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Habitat Use by Black Bears in Relation to Forest Management in Pisgah National Forest, North Carolina

Allan Joseph Brody
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Allan Joseph Brody entitled "Habitat Use by Black Bears in Relation to Forest Management in Pisgah National Forest, North Carolina." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

James Carter, Edward Clebsch, Ralph Dimmick

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Ralph W Dimmick

Accepted for the Council:

C W Minkel

The Graduate School

HABITAT USE BY BLACK BEARS IN RELATION TO FOREST MANAGEMENT IN PISGAH NATIONAL FOREST, NORTH CAROLINA

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Allan Joseph Brody

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ABSTRACT

A total of 1310 locations was obtained on 18 radio collared black bears (Ursus americanus) in Pisgah National Forest, North Carolina, during 1982 and 1983. Male home ranges averaged 3205 ha in summer and 6931 ha in fall. Female home ranges averaged 872 hectares in summer and 1712 hectares in fall. Nine of the collared animals were killed by hunters during the study, 4 of these illegally.

Bear habitat use was analyzed in relation to timber management parameters available on the U.S. Forest Service "Continuous Inventory of Stand Condition" and other parameters derived from stand and topographic maps. Chi-square analysis indicated that bears preferred yellow poplar-oak and brush cover types at the expense of softwood cover types; oak-hickory stands were used in approximate proportion to their availability. In summer bears preferred stands less than 10 years old and stands between 50 and 70 years old; during the fall the preference for young stands disappeared but the preference for stands 50 to 70 years old continued. Minor differences related to sex and year were noted, but in general these patterns were related to food habits; summer soft mast is available in recent clear cuts; fall hard mast is relatively abundant in the 50 to 70 year old stands as acorn production in most oaks peaks at this age. Preference for yellow poplar-oak stands over oak-hickory stands may be

due to annual differences in mast production between types, and the greater availability of other foods in the yellow poplar-oak stands.

Other habitat variables considered in the analysis of habitat use included stand condition, operability, method of cut, management type, topography, habitat diversity, and road density. Significant preferences or avoidances of categories within these variables were less easily explained, in part because some data useful in timber management have little relevance to bear habitat use.

Multiple regression models considering all the above mentioned variables with bear use of individual stands as the dependent variable were constructed. These models explained approximately 15% of the variance in habitat use. Inclusion of understory community data, which were available for only a small part of the study area, increased the variance explained to approximately 30%.

A regression analysis relating the number of times individual bears crossed roads to the density of roads in the home range indicated that logging road densities may begin to restrict bear movements at densities of 1.25 km/km^2 and that open improved roads may begin to restrict bear movements at densities of 0.5 km/km^2.

Conclusions from the study were that hunting is the primary human activity affecting bears in the study area. The current program of regenerating 10% of the area every decade may ensure a stable food supply by making 50 to 70 year old mast producing stands available consistently through time. However, the benefits of regeneration through clearcutting must be weighed against the increased vulnerability of bears to hunting which will result from roads constructed in association with clearcutting.

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I. INTRODUCTION

Generalists adapted to a forest environment (Herrero 1972), black bears originally inhabited all forested regions of North America and even today can be found in habitats as diverse as boreal forests, deciduous forests, subtropical swamps, and high elevation deserts. Yet direct pressures from man, in the form of hunting, and indirect pressures, in the form of habitat destruction, have substantially reduced the range of this species. Nowhere is this reduction more apparent than in the eastern United States, where bears survive in a few islands of semi-wilderness habitat surrounded by large expanses of agricultural and urban development.

As human populations and demands for natural resources increase, it becomes more and more imperative that land management decisions influencing bears be based on sound biological data. Research efforts to provide these data have been underway in nearly every physiographic region of bear range in North America during the past 2 decades. Despite these efforts, specific habitat requirements for black bears have not been described in the literature; this may be because habitat requirements for the species are not specific. Their generalist nature and intelligence have allowed bears to adapt and persist under a variety of environmental conditions and perturbations.

The majority of remaining bear habitat is federal land. In the southern Appalachian Mountains, the United States Forest Service (USFS) administers approximately 260,000 ha of bear habitat in Virginia, Tennessee, North and South Carolina, and Georgia; the United States National Park Service administers approximately 220,000 ha of bear habitat primarily in Tennessee and North Carolina.

The majority of black bear research in the southern Appalachians has been conducted in the Great Smoky Mountains National Park (GSMNP or Park), a 200,000 ha reserve protected from all consumptive use by humans. Work by Beeman and Pelton (1980) and Eagle and Pelton (1983) documented that bears are omnivores, surviving on herbs, grasses and squaw root (Conopholis americana) in the spring, soft mast, primarily of the Heath (Ericaceae) and Rose (Rosaceae) families in the summer, and hard mast, primarily acorns (Quercus spp.) and hickory nuts (Carya spp.) in the fall. Animal foods, mostly social insects, make up about 10% of the diet throughout the year.

The annual home range size for female bears in GSMNP was reported to be between 500 h and 800 h, while male ranges averaged between 1200 h and 3600 ha (Garshelis and Pelton 1981, Quigley 1982, and Carr 1983). Seasonal differences in home range size, activity centers, diel activity patterns, and movements frequently were noted, and nearly always were related to the phenology, production and geographic distribution of food resources (Garshelis and Pelton 1980, Garshelis et al. 1981, Quigley 1982, Carr 1983).

Pelton and Burghardt (1976) estimated the population in GSMNP at approximately 1 bear per 2.6 km^2 (1 $mile^2$). Previous research on reproduction of bears in the Park (Eiler 1981, Wathen 1983) related recruitment rates to the food regime, particularly the quality of the fall acorn crop.

The GSMNP is the extant environment most similar to the "pristine" regional environment in which black bears have existed for the last few thousand years, and as such the ecology of bears in the GSMNP may serve as a baseline from which to judge the degree of perturbation in the ecology of bears in more disturbed areas nearby, especially the national forests. Yet it is unclear how much of the GSMNP information can be applied to bear populations in the surrounding forests, because of the adaptability of black bears and the radically different management regimes on the national forests. Specifically timber harvests and bear hunting, both of which are illegal in the GSMNP, are major influences on the national forests. Hunting increases the mortality rate and can affect age and sex ratios; timber harvest transforms the more natural "gap-phase replacement" dynamics of small patches in the forest (Shugart 1984) into a larger scale mosaic of even-aged stands. The effects of timber harvest may interact with those of hunting by altering bear use of habitat, and, importantly, by increasing hunter access to bears through the construction of roads, which are an integral part of timber harvest activities.

In response to an increasing awareness of the need for integrating individual resource management activities, and the need for region-wide long term wildlife species management plans, USFS has recently initiated the "Wildlife and Fish Habitat Relationships Program" (Nelson and Salwasser 1982). The backbone of this program will be a series of habitat capability models for important wildlife species. These models are to be parameterized in such a manner as to allow integration into existing forest simulation and optimization models (Boyce 1980).

Given the importance of black bears as both game animals and symbols of wildlands in the southern Appalachians, this study was initiated by the National Forests in North Carolina as a first step in gathering the information necessary to integrate bear management into general management plans. Specific objectives of the study were as follows:

- to determine patterns of habitat use by black bears in an area of Pisgah National Forest.
- to relate these patterns to habitat characteristics, particularly those data used by USFS in timber inventory.
- to take the first steps in producing a descriptive/ predictive model of bear habitat use in relation to timber management parameters.

II. STUDY AREA

Location

The study area consisted of approximately 11,400 ha on the French Broad Ranger District of Pisgah National Forest in Haywood County, North Carolina (Figure 1). The area is bounded by the GSMNP on the west, the Tennessee state line on the north, the Madison County (North Carolina) line on the east, and by Walters Lake and private land in the Fines Creek community on the south. The Pigeon River drains the area, running in a generally northern direction. Major tributaries include Hurricane Creek, Cold Springs Creek, and Ground Hog Creek from the east, Dicks Branch and Mt. Sterling Creek from the west. Highway Interstate 40 (I-40) lies in the Pigeon River gorge and bisects the area; the area west of I-40 is known locally as the "Twelve Mile Strip" (TMS); that to the east, as "Harmon Den."

Geology

Harmon Den and the TMS are in the Unaka chain of the Blue Ridge physiographic province of the southern Appalachian Mountains. The TMS is the eastern terminus of the Great Smoky Mountains Range; Harmon Den is the western terminus of the Bald Mountains Range (Fennemen 1938). As is characteristic of the Unakas the terrain is steep, with mountain slopes averaging over 30% (Finlayson 1957) and the topography highly dissected with spring-fed streams forming a dendritic drainage pattern. Elevations range from 439m at Waterville to 1411m at Max Patch Mountain. The Appalachians overlie

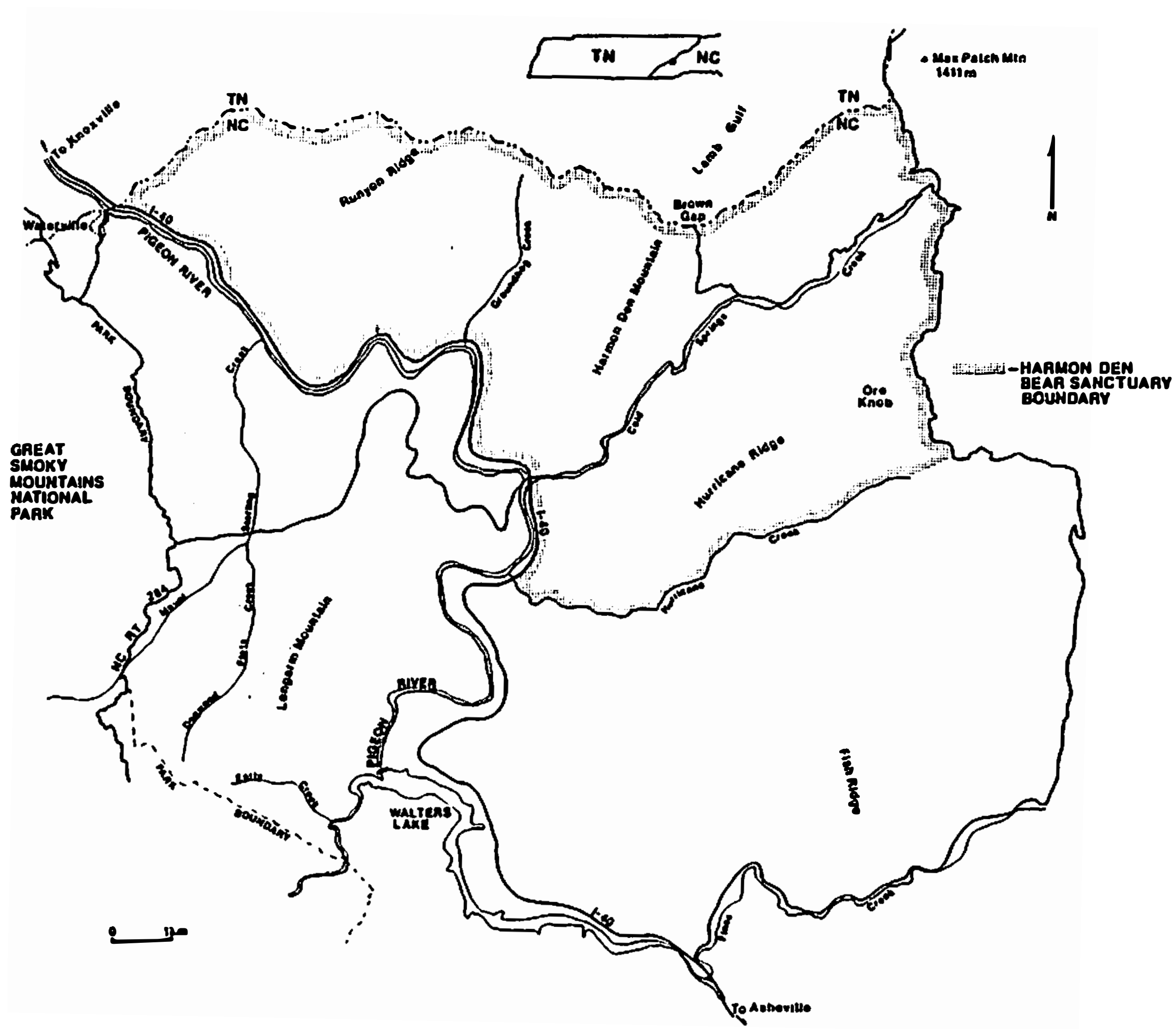

Figure 1. The Harmon Den-Twelve Mile Strip study area in Pisgah National Forest, North Carolina.

an immense regional thrust belt; the Meadow Fork Fault is a major low angle thrust fault running between and parallel to Cold Springs Creek and the Tennessee state line mountain crests.

Geologic formations and soil parent materials are complex. Granite and gneiss are the predominant exposed rocks south of the Meadow Fork Fault; sedimentary rocks of the Snowbird formation are exposed north of the fault. Phyllites are frequent in shearing zones, landslides are common where sharply tilted phyllite bedrock is exposed, such as along the I-40 road cut (Finlayson 1957, Young et al. 1977).

Climate

Thornthwaite (1948) classified the climate of the southern Appalachians as "mesothermal perhumid," characterized by hot humid summers, short mild winters, and relatively long spring and fall seasons. Mean annual temperature at Waterville is 12.9 C.; the coldest month is January (average 3.3 C.), the warmest is July (average 22.6 C.). There are an average of 150 frost-free days per year (National Oceanographic & Atmospheric Administration [NOAA] 1973).

Precipitation ranges from an average of 1063 mm per year at Waterville to 1515 mm per year at Max Patch (NOAA 1980). Winter precipitation patterns are cyclonic, affected by both warm maritime air masses from the Gulf of Mexico and cold continental masses from Canada. Most winter precipitation falls as snow but accumulations are minimal. Summer precipitation is mostly orographic; heavy afternoon thunder storms are frequent. November is the driest month, averaging 92 mm of precipitation. Precipitation peaks in March and July, each averaging 144 mm. Precipitation exceeds evapotranspiration every month (NOAA 1980).

Biota

Flora. Whittaker (1956) found neighboring GSMNP to be among the most botanically diverse temperate areas in the world. King and Stupka (1950) listed over 1300 native species of flowering plants, including 131 species of trees, in the Smokies. Studies by Whittaker (1956), Golden (1981) and Callaway (1983) have related this diversity and accompanying vegetation patterns to topographic diversity and the warm wet climate. Because elevation extremes in the Harmon Den-TMS area are not as great as in GSMNP, the flora of the study area is a subset of that of the Park. Essentially absent from Harmon Den are the low elevation pine types (Table Mountain Pine-Heath and lower) and high elevation Spruce-Fir type of Whittaker (1956).

The Forest Service classifies forest tree communities into "forest cover types" which are named and delineated on the basis of dominant vegetation; species making up 70% or more of the dominant vegetation in the community give their name to the type (Society of American Foresters 1980). Twenty-four cover types occur in the study area, although 5 hardwood types together cover approximately 90% of the area (Table 1).

Fauna. Linzey and Linzey (1971) list 59 species of mammals inhabiting GSMNP; King and Stupka (1950) claim that more than 200

Table 1. U.S. Forest Service forest cover types[a] on Harmon Den and Twelve Mile Strip, Pisgah National Forest.

Forest Cover Type (Code)	Dominant Species
Pine Types--Stands in which 70% or more of the crowns in dominant and codominant position are softwoods with the type species prevailing:	
White Pine (03)	Pinus strobus
White Pine-Hemlock (07)	P. strobus, Tsuga canadensis
Virginia Pine (33)	P. virginiana
Pitch Pine (38)	P. rigida
Table Mountain Pine (39)	P. pungens
Pine-Hardwood Types--Stands in which 51-69% of the crowns in the dominant and codominant position are softwood species with the type species prevailing:	
Hemlock-Hardwood (08)	T. canadensis; + Fagus grandifolia, Prunus serotina, Betula allegheniensis, Magnolia fraseri
White Pine-Cove Hardwood (09)	P. strobus; + Liriodendron tulipifera, Prunus serotina, F. grandifolia, Halesia carolina, B. allegheniensis
White Pine-Upland Hardwood (10)	P. strobus; + F. grandifolia, Acer saccharum, B. alleghenensis
Shortleaf Pine-Oak (12)	P. echinata; + Quercus falcata, Q. velutina
Pitch Pine-Oak (15)	P. rigida; + Q. coccinea, Q. prinus
Virginia Pine-Oak (16)	P. virginiana; + Q. coccinea, Q. prinus

Table 1 (Continued)

Forest Cover Type (Code)	Dominant Species
Hardwood Pine Types--Stands on which 51-69% of the crowns in the dominant and codominant positions are hardwood species with the type species prevailing:	
Cove Hardwoods-White Pine-Hemlock (41)	L. tulipifera, F. grandifolia, Prunus serotina; + P. strobus, T. canadensis
Upland Hardwoods-White Pine (40)	F. grandifolia, A. saccharum, B. allegheninsis; + P. strobus
Southern Red Oak-Yellow Pine (44)	Q. falcata; + P. rigida, P. pungens
Chestnut Oak-Scarlet Oak-Yellow Pine (45)	Q. prinus, Q. coccinea; + P. rigida, P. pungens
No. Red Oak-Hickory-Yellow Pine (48)	Q. rubra, Carya tomentosa, C. glabra, C. cordiformis; + P rigida, P. pungens
Hardwood Types--Stands in which 70% or more of the crowns in the dominant and codominant positions are hardwoods with the type species prevailing:	
Yellow Poplar (50)	L. tulipifera
Chestnut Oak (52)	Q. prinus
White Oak-Red Oak-Hickory (53)	Q. alba, Q. falcata, Q. rubra, C. tomentosa, C. cordiformis, C. glabra
Yellow Poplar-White Oak-red Oak (56)	L. tulipifera, Q. alba, Q. falcata, Q. rubra
Northern Red Oak (55)	Q. rubra
Scarlet Oak (59)	Q. coccinea
Sugar Maple-Beech-Yellow Birch (81)	A. saccharum, F. grandifolia, B. alleghenensis
Brush species (99)	Rhododendron spp., Kalmia latifolia

[a]United States Forest Service, 1981a, Silvicultural examination and prescription handbook--Region 8. Atlanta, GA, 50 pp.

species of birds, 80 species of reptiles and amphibians, and 80 species of fishes are found there also. Again, because of the smaller size and more restricted elevations of TMS and Harmon Den, many of these species probably cannot be found in the study area. Big game species that share the study area with black bears include white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*). Other native carnivores observed in the area during the study included bobcat (*Felis rufus*), raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), grey fox (*Urocyon cinereoargenteus*), and weasel (*Mustela* sp.). European wild hogs (*Sus scrofa*), coyotes (*Canis latrans*) and feral dogs (*C. familianis*) are exotics that occur only sporadically in the study area.

History

Recorded accounts of the early history of the TMS and Harmon Den area of Haywood County are few, but the Cherokee Indians undoubtedly inhabited the region before white settlers arrived in the late 1700's (Dykeman 1965). The first settlers were farmers; commercial logging started in the late 1800's. Except for a small amount of timber on the TMS, essentially the entire area was cleared, logged, or burned between 1850 and 1940. The human population of the area peaked in the 1920's (J. MacElroy, Fines Creek, pers. com.), and careful observation reveals abandoned cornfields or pastures scattered through every major drainage in the area, even in those inaccessible by road or trail today. The area contains at least 11 cemeteries.

In the 1930's the United States Forest Service began condemning and/or buying private land to establish the French Broad Ranger District of Pisgah National Forest. The land acquisition process continues today; a parcel of Appalachian bald on Max Patch Mountain was purchased by USFS in 1982. Currently there are 8 tracts of private land, totaling approximately 350 ha, completely surrounded by approximately 11,000 ha of USFS land. Additionally, there are several large fingers of private land extending into the area. Most of these private holdings have dwellings on them, but only 2 are permanently inhabited.

Several small communities are immediately adjacent to the area. The villages of Mt. Sterling and Waterville, with a combined population of approximately 75, lie at the north-east end of TMS. Maple Spring Gap, population 25, is located at the head of Hurricane Creek. Fines Creek and White Oak, with a combined population of near 1000 lie immediately south of the area. The Lamb Gulf of Cocke County, Tennessee, is north of the study area, supporting a scattered rural population. The closest incorporated cities are Waynesville, North Carolina (population 7000), 25 km to the south, Hot Springs, North Carolina (population 1000), 25 km east, and Newport, Tennessee (population 9000) 35 km north.

Interstate 40, the major east-west route through Tennessee and North Carolina, traverses the study area along the Pigeon River. I-40 was completed through the area in the 1970's; previously no roads penetrated the Pigeon River gorge between Fines Creek and the Tennessee state line, although a narrow gauge rail spur ran from Canton down the gorge to Cold Springs Creek in the early 1900's. Major repairs of I-40 between Cold Springs and Waterville were underway during this study. The Pigeon River, which has been badly polluted (by papermill effluent from a plant at Canton) since the 1920's, is diverted at Walters Lake and runs through an underground flume to a small generator operated by Carolina Power and Light Company at Waterville.

Because of the proximity to GSMNP, the Blue Ridge Parkway, and its mountain setting, Haywood County's economy today is based on tourism. Yet there are essentially no facilities for tourists, and only a few vacation homes, in the Fines Creek-Harmon Den-Waterville area of the county. Cattle farming, dairy farming, and logging (particularly through USFS timber sales) are the major economic pursuits here. Cultivation of marijuana provides an illegal but profitable economic base for some residents of the area--at least 4 such fields were observed in the area during this study.

Recreational use of the study area can be heavy at times, but except for hikers on the Appalachian Trail use is almost entirely by local residents. Residents of Fines Creek and Waynesville camp frequently in the area; horseback riding and fishing the stocked waters of Cold Springs Creek are the major recreational activities during the summer. During the fall hunting seasons use is extremely heavy. Bear hunting is particularly popular; it is a large part of the hunting tradition of the southern Appalachians, and in fact, the Plott Hound (a premier bear hunting dog) was first bred in Haywood

County. J. MacElroy (pers. comm.) estimates that at least one-third of the local men (perhaps 150 individuals) are active bear hunters.

USFS Management

Objectives. The Multiple Use-Sustained Yield Act of 1960 requires that national forests be managed for the sustained yield of all resources, including timber, recreation, wildlife, watershed, and range. The National Forest Management Act of 1976 requires that national forest management objectives be integrated into long range Forest Plans. The required planning process is complex, calling for much public input and consideration of several management alternatives. The Pisgah National Forest is currently in the process of reviewing these alternatives; a Final Forest Plan for the area has yet to be completed (USFS 1982b). Presently, management objectives are not centralized in a single document and are subject to revision as needs arise and pressures demand. What follows is a summary of several documents (USFS 1971, 1981a, 1981b, 1982a, 1982b), conversations with USFS and North Carolina Wildlife Resources Commission (NCWRC) personnel, and personal observation.

Timber. Timber production is the primary management objective on the French Broad Ranger District; 50.9% (5744 ha) of the TMS-Harmon Den area is considered operable. Units are managed on a 60 to 100 year rotation, depending on cover type, site and productivity; clear-cutting and associated even-aged management is the preferred method of regeneration, both economically and ecologically. Wildfire is controlled, clear-cutting is viewed as a necessary and acceptable analog to the ancient fire regime. General long range goals call for regeneration of 10% of the area every decade. Operable slopes of greater than 40% are logged by cable, flatter areas are logged by tractor. There is a region-wide maximum limit of 16.2 h (40 acres) on the size of any hardwood clearcut unit. It should be noted here that 24% (16,223 ha) of the area has been regenerated since the USFS took control of the area approximately 50 years ago. (This is calculated solely from current stand ages, some of the area may not have been under USFS jurisdiction when it was regenerated.) Thus, conceivably, there is room for timber harvests totaling greater than 10% of the area per decade over the next few decades in order to bring the forest age distribution into line with the long range goals. The current age distribution of the forest stands is shown in Figure 2.

Although current policy claims to allow the cover type best suited to the site to regenerate after clear-cutting, past management practices frequently called for the release (through thinning or other silvicultural techniques) of commercially important species, such as yellow poplar and white pine, at the expense of oak and maple species. Currently 34% (3877 ha) of the area is in a cover type different from the management type (management type is defined as the forest type "best suited to the site" [USFS 1981a]); 11% (396 ha) of this area is scheduled for conversion to the management type, primarily through clear-cutting, during the current planning period.

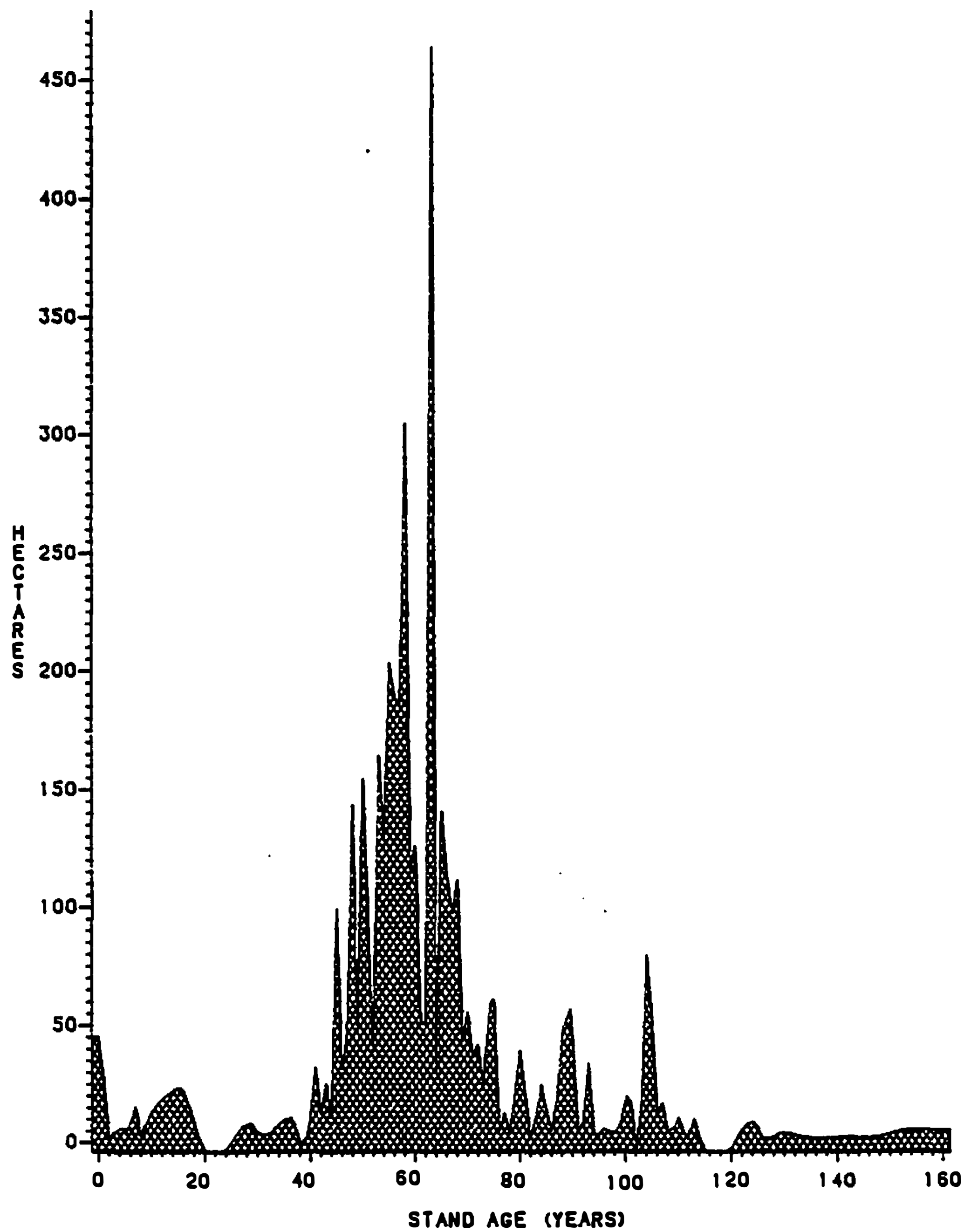

Figure 2. Age distribution of all forest stands on Harmon Den and the Twelve Mile Strip, Pisgah National Forest in 1983.

Table 2 compares the in-place areas and the management type areas for each forest cover type. Note that while "pure" yellow poplar (type 50) is in place on 7% (801 ha) of the area, it is not considered to be the management type anywhere on the area.

Recreation. Aside from timber management, the multiple use concept requires that other management needs be addressed, including recreation and wildlife. As previously stated, recreational use of the area is almost exclusively by local residents but I-40 makes the area very accessible and there is potential for increased use. Plans to develop a 70-site fee-for-use campground in the Cold Springs basin have been at least temporarily aborted, although minor development, such as the installation of several privies and the construction of an information bulletin board, has occurred in the last 2 years. Several kilometers of foot trails are maintained in Harmon Den, but only the Appalachian Trail receives anything but very infrequent use. More heavily used are the horse trails developed from temporary logging roads; these roads are seeded in grass and clover and maintained free of brush, but closed by physical barriers to motor vehicles. There is a small set of rails for tying horses in the Cold Springs basin.

Wildlife. Wildlife on the Pisgah National Forest is managed in cooperation with NCWRC in the North Carolina Gamelands program. The USFS addresses wildlife management needs through the "featured species" program, in which a wildlife species of recreational or

Table 2. Area of Forest Cover Types and Management Types on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, North Carolina.

Forest Type (Code)[a]	Hectares in Forest Cover Type[b]	Hectares in Management Type[b]
Non-forest (0)	377	377
White Pine (3)	193	1,425
White Pine-Hemlock (4)	45	0
Shortleaf Pine (32)	0	15
Virginia Pine (33)	69	12
Pitch Pine (38)	75	4
Table Mountain Pine (39)	4	0
Hemlock-Hardwood (8)	126	0
White Pine-Cove Hardwood (9)	235	0
White Pine-Hardwood (10)	229	0
Shortleaf Pine-Oak (12)	15	0
Pitch Pine-Oak (15)	10	0
Virginia Pine-Oak (16)	5	0
Cove Hardwoods-White Pine-Hemlock (41)	60	0
Upland Hardwood-White Pine (42)	334	0
Chestnut Oak-Scarlet Oak-Yellow Pine (45)	208	0
Southern Red Oak-Yellow Pine (44)	27	0
Northern Red Oak-Hickory-Yellow Pine (48)	37	0
Yellow Poplar (50)	801	0
Chestnut Oak (52)	601	0
White Oak-Red Oak-Hickory (53)	4,444	5,313
Northern Red Oak (55)	28	0
Yellow Poplar-White Oak-Northern Red Oak (56)	2,784	4,065
Scarlet Oak (59)	498	0
Sugar Maple-Beech-Yellow Birch (81)	71	60
Brush (99)	10	5
	11,285	11,285

[a]See Table 1, page 9, for explanation of types.

[b]United States Forest Service, 1982a, Continuous inventory of stand condition summary, French Broad Ranger District, Asheville, N.C.

ecological concern is featured in each compartment, and the wildlife management activities in that compartment are based on that species' habitat needs. Turkey are featured on Harmon Den, bear are featured on the TMS. Management practices for turkey call for providing brood range through maintenance of open grassy areas. Temporary roads seeded in grass and clover meet this objective. There are approximately 29 km of these "strip openings" in Harmon Den (many of these openings simultaneously serve as horse trails). Additionally, USFS (1971) calls for maintaining certain percentages of each compartment in softwood, for cover and roosting, and/or mature mast species for fall food, depending on management types and sites.

Designated management activities are less specific for bear; this likely reflects the relatively generalist nature of the species. USFS (1981b) calls for the retention of at least 20% of a compartment in "mast and den producing capability" (p. 409.34) (i.e., mature mast species) through regeneration, conversion, or establishment of key areas. Optimum hardwood rotation is given as 80 to 100 years, with the preservation of old snags as den trees. Additionally, management practices for bears call for maintenance of domestic fruit trees at abandoned home sites, preservation of grape slicks (*Vitis* spp.), and restriction of road access into bear range.

Bear hunting in Haywood County was open for 9 weeks, split into 2 fall seasons, during the 2 years of this study; this type of season has been the norm in western North Carolina since 1969. Harmon Den north of Hurricane Creek has been a NCWRC bear sanctuary since 1971, but the TMS and the private lands south and east of the sanctuary historically have reported high bear kills. Pursuit with dogs is by far the most popular method of hunting bears in the area; baiting is legal on private land but bears may not be shot over bait. Long time residents of the area (J. MacElroy, E. Hannah, pers. comm.) claim that the bear population has increased substantially since USFS took control of the area 50 years ago, while others (S. Ferguson, W. Messer) claim that the population has declined over the last decade.

Wilderness. Of special concern is the essentially roadless area of Harmon Den between I-40, the Appalachian Trail, the Brown Gap Road and Cold Springs Road. This approximately 2800 ha was under consideration for wilderness designation by the "Roadless Area Review and Evaluation, Phase 2" process, but was dropped from consideration in 1979. Since then approximately 7 km of permanent gravel roads and 2 km of temporary roads have been constructed in association with timber sales on the eastern edge of the area along Harmon Den Mountain. The remainder of the timber has not been disturbed since the 1920's.

Continuous Inventory of Stand Condition

The USFS uses the "Continuous Inventory of Stand Condition" (CISC) system to manage resources on Pisgah National Forest. The basic unit of management is the "stand," the average size of stands in the TMS-Harmon Den area being 19.5 ha (USFS 1982a). Compartments consist of groups of 6 to 40 contiguous stands. Certain data are recorded for each stand, and updated continuously. A complete description of these parameters is given in USFS (1981a); descriptions pertinent to this study are given in Table 3. Stand boundaries are delineated by USFS personnel or contracted foresters, and as such, boundaries and assigned values of some CISC parameters may be somewhat subjective. Since assigned values necessarily apply to the entire area within a stand boundary, attempt is made to delineate boundaries coincident with discrete natural ecological and economic units. Frequently, though, there may be small (less than 5 ha) areas within a stand in which the forest characteristics do not match those assigned to the stand (L. Hillman, USFS, pers. comm.).

Table 3. Description of stand parameters used in the CISC System, Pisgah National Forest.

Parameter	Class (Code)	Notes	Hectares in Study Area
Operability	Inoperable (01)	Steep slopes, unstable soils or low accessibility	5,746
	Pine poletimber (02)	<9.0" diameter at breast height (DBH)	138
	Small pine sawtimber (03)	9.0" DBH - 14.9" DBH	53
	Large pine sawtimber (04)	>15.0" DBH	0
	Hardwood poletimber (05)	<13.0" DBH	2,042
	Small hardwood sawtimber (06)	13.0" DBH - 18.9" DBH	28
	Large hardwood sawtimber (07)	>19.0" DBH	27
	Operable multiple products (08)		1,711
	Pine & hardwood poletimber (11)		80
	Pine & hardwood sawtimber (12)		12
	Mixed poletimber and sawtimber (13)		204
	Hardwood poletimber and sawtimber (14)		748
	Pine poletimber and sawtimber (15)		77

Table 3 (Continued)

Parameter	Class (Code)	Notes	Hectares in Study Area
Method of Cut	No cutting (1)		6,123
	Clearcutting (2)		2,012
	Thinning (5)		3,122
	Shelterwood cutting (4)		6
	Sanitation cutting (6)		15
Condition	In regeneration (01)		332
	Damaged poletimber (02)		34
	Damaged sawtimber (03)		0
	Sparse poletimber (05)		23
	Sparse sawtimber (06)		248
	Low quality poletimber (09)		586
	Low quality sawtimber (08)		188
	Mature poletimber (09)		7
	Mature sawtimber (10)		843
	Immature poletimber (11)		3,848
	Immature sawtimber (12)		4,541
	Seedling & sapling (13)		250
	Not stocked (15)		10
Age	Recorded as birthdate of stand	Determined by increment boring	
Site Index	Given to nearest 10 feet	Defined as the height of a 50 year old tree of the management type in place on the stand. Determined from measurements on an index tree and USFS tables.	

III. METHODS

General Approach

Habitat utilization studies have been conducted for a large number of wildlife species. An underlying assumption in many of these studies is that there is a non-random use of available habitat resources, and that this non-random pattern of resource utilization is related to the species' life history requirements (Kincaid and Bryant 1983). There have been at least 2 general approaches taken in investigations of wildlife habitat use. The earliest is that of Ivlev (1961) in which the resources used are functionally compared to the resources available, and preference or avoidance for the particular resource in question is inferred. The work of Neu et al. (1974), Chesson (1978), Strauss (1979), Vanderploeg and Scavia (1979), Johnson (1980), and many others are based on this principle. This approach has 2 short-comings. First, analysis is restricted to 1 type of resource at a time--food types, cover types, or topographic position, etc., but not all types at the same time. Second, there is no *a priori* reason why a non-random use of available resources should indicate anything about the importance of particular resources to a species; in fact, it could be argued that the perfectly adapted species uses resources in exact proportion to their availability. Recently Kincaid and Bryant (1983) have addressed at least the first problem with their "geometric method," but while the method appears theoretically sound it will be hard to apply to field situations because it requires that different resources be measured in similar units.

A second approach to elucidating habitat resource utilization patterns is through multivariate statistics. Commonly, some measure of a species' use of a particular site is regressed on a host of habitat variables for that site. More sophisticated statistical techniques, such as principal components or other types of factor analysis, are frequently applied to reduce the biases of colinearity between independent variables (Shugart 1981). Statistical coefficients different from 0 indicate that animal use of a site is related to the value of those habitat variables. A problem with this approach is, while regression techniques require continuous variables, many habitat values are categorical. Multivariate categorical techniques that could address this problem have become available recently (Statistical Analysis System 1979, Swafford 1980) but to my knowledge they have not yet been applied to studies of wildlife habitat use. The multivariate statistical approach has been taken in most of the recent models of wildlife habitat capabilities (e.g., Boyce 1981, Sczerzimie 1981, Solis 1982).

A more fundamental question than <u>how</u> to relate habitat use to habitat characteristics is <u>what</u> variables to examine in the relationship. In wildlife studies these decisions are often governed more by circumstance than by theory. In the case of large solitary mammals, radio telemetry is by far the most efficient method of gathering locational data that can indicate habitat use and as such was chosen for use in this study. Similarly, the USFS CISC data base was already available, and use of CISC as habitat data made the analyses relevant to USFS management plans as well as alleviating the need to gather habitat data in the field.

Trapping

Bears were trapped in order to afix radio collars. Three traplines were established. Lines on Longarm Mountain and Hurricane Ridge lines were checked from a vehicle, a line on Harmon Den Mountain was checked on foot. Traps were opened intermittently between June and September in 1982 and 1983.

Modified Aldrich foot snares were used to capture bears using methods described by Johnson and Pelton (1980a). In 1982 captured bears were immobilized with M99 (etorphine hydrochloride, D-M Pharmaceuticals, Rockville, MD) at a dose of 1 mg per 45 kg; after processing they were reversed with a 2 mg per 45 kg intravenous injection of M50-50 (diprenophrine hydrochloride, D-M Pharmaceuticals, Rockville, MD). In 1983, bears were immobilized with intramuscular injections of a mix of Ketaset (Ketamine hydrochlorida, Bristol Laboratories, Ssyracuse, NY), Rompum (Xylazine, Haver-Lockhart, Inc., Shawnee, KS) and Carbocaine V (Mepivacaine hydrochloride, Winthrop Laboratories, New York, NY) at a dose of 200 mg, 100 mg, and 20 mg per 45 kg, respectively. Immobilization drugs were administered by darts fired from a carbon dioxide-powered pistol (CAPCHUR, Palmer Chemical Company, Douglasville, GA).

Immobilized animals were weighed and general and reproductive conditions were noted (Eiler 1981). One premolar tooth was extracted for animal age determination in the laboratory using the techniques of Willey (1974) and Eagle and Pelton (1978). All captured bears were ear-tagged and lip tatooed (Johnson and Pelton 1980b).

Radio Telemetry

Most bears were fitted with motion-sensitive radio collars operating in the 151-152 Mhz range (Telonics, Mesa, AZ). Young animals' collars were designed to "break-away" as the animal grew. Telonics TR-2 receivers, TDP-2 digital signal processor and 2-element yagi antenna were used to track the collared animals. Visual observation of radio-tracked bears was extremely rare and not often attempted. Ground tracking was accomplished through triangulation using the "loudest signal method" (Springer 1979). Directional integrity of radio signals was affected by the dissected terrain and thick vegetation, so Springer's (1979) error polygon method was used to establish 94% confidence areas on each location. From 3 to 7 azimuths for each animal location were taken and roughly plotted on USGS 1:24000 topographic maps in the field. From these azimuths 2 were chosen to construct the error polygon for each location. Criteria used to decide which azimuths would be used for a given location included signal strength and integrity, angle between readings, time between readings, and approximate distance from receiver to animal. A computer program, "PLOTEQ," written in conjunction with this study, was used to calculate animal locations and error polygons. Program "NEWPLO" was used to draw each error polygon at a 1:24000 scale on tracing paper which could then be overlaid on USFS stand maps. With each azimuth taken the activity of the animal, based on the setting of the motion sensor (Quigley et al. 1979) was recorded along with weather conditions.

When the need and opportunity arose, far-ranging bears were tracked from Cessna 172 or Skymaster aircraft with yagi antennas mounted on each wing strut. The airplane homing technique is described by Carr (1983). A circle of 300 m diameter was used in place of calculated error polygons for aerial locations (Quigley 1982). Winter dens were located by homing on foot after first establishing the location of the den by ground triangulation or aerial homing.

Sampling Regime

Recent telemetry studies of black bears in the southern Appalachians (Garshelis and Pelton 1980, Garshelis et al. 1981, Quigley 1982, Villarubia 1982, Carr 1983, Garris 1983) have focused on seasonal variations in diel movement and activity patterns, and as such required diel monitoring of collared animals. The emphasis in this study, however, was on habitat use, and as such the best possible estimates of home range and habitat utilization distributions (Ford and Krumme 1979, Dixon and Chapman 1980, Anderson 1982) were desired. Data characterized by short time periods with many locations followed by relatively long periods with few locations have been criticized for the observations' lack of independence when these data are used to construct models of home ranges or utilization distributions (Dunn and Gipson 1977, Smith et al. 1981, Garshelis 1983). Dunn and Gipson (1977) have pointed out that the covariance between 2 successive locations depends only on the time interval between them, and that if that interval is constant between successive locations in the sample the probability distribution of the sample locations approaches that of the equilibrium condition. A constant sampling interval does not ensure independence (in fact, independence in animal location data may be impossible, probably _no_ 2 events in an animal's life are completely independent!) but can reduce sampling biases. The assumption was made that a constant sampling interval would yield a robust estimate of home range and utilization distribution. A sampling interval of 1 location on each collared bear in the study area every 20 hours was chosen because it seemed logistically reasonable and had the added advantage of distributing the sample locations evenly throughout the diel period, thus absorbing any effects of time of day on habitat use.

Data Analysis

Home ranges. Two techniques were employed to estimate home range boundaries and areas. The first method was based on that of Dixon and Chapman (1980), in which a utilization distribution is derived from the reciprocal mean distance deviations ("harmonic means") between the animal locations and a superimposed calculation grid. Following Spencer and Barrett (1983), the isopleth enclosing 95% of an animal's locations was used as the home range boundary. Modifications in the original algorithm recommended by Spencer and Barrett (1983) were incorporated into "HARMON," a computer program written as part of this study. "HARMON" was used to calculate and produce 1:24000 scale contour maps of the utilization distributions using the Surface II Graphics System (Sampson 1975) installed at the University of Tennessee Computing Center. Home ranges calculated by the harmonic mean method differ in shape and frequently in size from home ranges calculated by more traditional methods. In order to compare data from this study with that of others, the "convex polygon" method used by Garshelis and Pelton (1981), Quigley (1982), Carr (1983), and others was also used to determine home range areas. Areas were calculated using the computer program "HOME" (Harestad 1981).

Seasonal and annual home ranges were constructed. Seasonal definitions follow Carr (1983) except that spring was absorbed into summer because of the low number of locations obtained between den emergence and 31 May. The 2 seasons then defined were summer (den emergence to 31 August) and fall (1 September to den entrance). This breakdown is derived from previous work (Quigley 1982, Villarubia 1982) and the relationships between food habits and food-plant phenology (Beeman and Pelton 1980, Eagle and Pelton 1983).

The location and value of the harmonic center of animal activity (Dixon and Chapman 1980) for each seasonal range were used to compare seasonal shifts in home range location.

Habitat utilization. SAS (1979, 1982) descriptive, regression, and categorical procedures were used to analyze habitat use in relation to forest management parameters. Because regression techniques require at least quasi-continuous data, the CISC parameters listed in Table 3 (page 22) were grouped into the rank categories described in Table 4.

In addition to the CISC parameters, other data that could be gathered from the USFS or USGS maps were used in analysis. These parameters are described in Table 5 and fall into 3 categories: diversity variables, topographic variables, and road variables. The edge diversity variables attempt to measure the "beta" diversity of Nelson and Salwasser (1982), where the diversity of discrete types across a local area is considered. The ratio of linear edge to area is a measure of the stand's shape, and is included because edge has been used frequently in measures of wildlife habitat quality (Hays et al. 1981).

Values of topographic variables were derived from USFS "ecological management unit" maps (Young et al. 1977) which classify areas on the basis of slope, aspect, soil parent material, hydrologic regime, and degree of broad use limitation (a measure of the overall

Table 4. Groupings and ranks of CISC categories used in analysis of bear habitat use.

Parameter	CISC Class Code	Group for X^2 Analysis	Rank Value for Regression Analysis	Explanation
Forest Cover Type and Management Type	3,4,8,9,10,12, 15,16,33,36,39	Softwood Cover Types	1	Ranked in order of % of dominant trees that are mast producing
	41,42,44,45,48	Mixed Hardwood-Softwood Cover Types	2	
	50	Yellow Poplar	2	
	52	Chestnut Oak	5	
	53,81	White Oak-Red Oak-Hickory	4	
	56	Yellow Poplar-Oak	3	
	55,59	Scarlet Oak, Northern Red Oak	6	
	99	Brush	0	
Condition	1,13,15	No mature stems	1	Ranked in order of mature stem density
	2,5,6,7,8,11	Low density of mature stems	2	
	9,10,12	High density of mature stems	3	
Operability	0,1	Inoperable	1	Ranked in order of increasing basal area/ economic feasibility
	2,5,11	Poletimber	2	
	3,4,6,7,12, 13,14,15	Sawtimber	3	
Method of Cut	0,1	No cutting	1	Ranked in increasing order of severity of cut
	5	Thinning	2	
	2	Clearcutting	3	

Table 5. Variables derived from USFS or USGS maps and used in analysis of bear habitat use.

Variable	Explanation	Parameterization
Topographic Variables:		
Elevation	Average elevation of the stand. From USGS topographic maps.	Direct. To nearest 100 feet
Aspect	Coded from Ecological Management Unit[a] map. Average value of the stand.	Direct. Between 1 (northern exposure &-1 (southern exposure)
Degree of Broad Use Limitation	Coded from Ecological Management Unit[a] map Average value of the stand.	Ranked: 1 = moderate; 2 = critical; 3 = severe
Topographic Diversity	Coded from Ecological Management Unit[a] map Shannon-Weaver Diversity Index[b] calculated from the number and proportion of Ecological Management Units[a] within the stand.	Direct. 0 = no diversity, increasing to high diversity
Biological Diversity Variables:		
Edge-Age	Shannon-Weaver Diversity Index,[b] calculated from the number and proportion of age classes of surrounding stands. Age classes were 20 year intervals centered on the age of the stand.	Direct. 0 = no diversity, increasing to high diversity
Edge-Cover Type Diversity	Shannon-Weaver Diversity Index,[b] calculated from the number and proportion of cover types surrounding the stand. Cover type groups as described in Table 4, page 30.	Direct. 0 = no diversity, increasing to high diversity
Edge-Area Ratio	Coded from USFS stand maps. Linear amount of edge of the stand divided by the area of the stand.	Direct. meters/hectare

Table 5 (Continued)

Variable	Explanation	Parameterization
Road Variables:		
Unrestricted improved road density	Coded from USFS transportation maps. Paved, graveled or good dirt roads permanently open to the public. Length of road divided by the area of the stand.	Direct. km/km^2
Unrestricted 4-wheel drive road density	Coded from USFS transportation maps. Unmaintained or poor dirt roads that are permanently open to the public. Length of road divided by the area of the stand.	Direct. km/km^2
Restricted access-improved road density	Coded from USFS transportation maps. Light duty maintained roads behind locked USFS gates. Generally these are logging roads. Length of road divided by the area of the stand.	Direct. km/km^2
Permanently closed or abandoned road density	Coded from USFS transportation maps and USGS geographic maps. Generally these are old logging roads that have been seeded and blocked with physical barriers. Length of road divided by area of the stand.	Direct. km/km^2
Additional Variable:		
Mast capability	Derived from CISC data and based on USFS mast capability guidelines[c] according to age of the stand.	Ranked in order of increasing mast production capability: Non-mast cover type or stand age less than 26 years = 0. Stand age between 26 & 40 years = 1. Stand age between 40 & 50 years or greater than 70 years = 2. Stand age between 50 & 70 years = 3.

[a]Young, C. H., D. Manning, and J. D. Joslin. 1977. National Forests in North Carolina French Broad Ranger District Soil Resource Inventory Planning Unit 18, Soil Resource Inventory Report, April 1977, 41 pp.

[b]Shannon, C. E., and W. Weaver, 1949, The mathematical theory of communication, University of Illinois Press, Urbana.

[c]United States Forest Service, 1971, Wildlife Management Handbook--Region 8, Atlanta, GA.

physical suitability of a stand for engineering or timber operations). An additional variable, the "mast capability factor," which is based on cover type and age of the stand (USFS 1971), was also included in the analysis.

ANOVA (SAS 1979) techniques and the Chi-square techniques of Neu et al. (1974) were used to describe bear use of categories of each variable. All variables were combined into a regression model where the percentage of bear locations in each stand served as the dependent variable, and the independent variables were those described in Tables 4 and 5. Percentages were arcsine transformed (Sokal and Rohlf 1981) and regressions were weighted by the percentile value of the harmonic mean for each stand. This weighting was employed to accentuate the variance of the generally small range of percentages resulting from the small size of a stand in relation to a home range. The weighting is rationalized by assuming that use or avoidance of a stand near the center of an animal's home range is more indicative of the importance of the characteristics of that stand to the animal than is use or avoidance of a stand on the edge of its home range. Separate models were constructed for each sex and season, and for each bear where appropriate.

Noticeably absent from the independent variables used in the models are any variables pertaining to understory characteristics. In the past USFS has collected "wildlife" data describing understory composition and abundance, and hard and soft mast capabilities, but this practice ended in the late 1970's. Data for 4 compartments were still on record at the District Ranger's Office and these data were incorporated into regression models in attempt to improve the predictive capability of the models. These data and their parameterization for the models are described in Tables 6 and 7.

Determining the effect of roads. Many studies have implicated roads as factors decreasing the quality of bear habitat. Hamilton (1978) documented an avoidance of roads by bears in coastal North Carolina, Miller (1975) and Brown (1980) found similar avoidance in West Virginia. In the southern Appalachians Quigley (1982) and Villarubia (1982) claimed that bears avoided roads in GSMNP and Cherokee National Forest, respectively, while Carr (1983) reported little effect of roads on bear habitat use in GSMNP.

Quigley (1982) and Carr (1983) arrived at their conclusions by testing the number of radio locations within 200m of a road against the amount of their study area within 200m of a road with the Chi-squared method of Neu et al. (1974); Villarubia used the same statistical technique but tested the number of radio locations in the same 100m grid square as a road against the number of grid squares containing roads. In all 3 studies the distances used to define proximity to roads are somewhat arbitrary (and also somewhat suspect considering that the reported resolution of radio locations for all 3 studies was a circle of 300m diameter), especially when it is acknowledged that being 200m away from a road in a new clearcut is certainly a different ecological situation than being 200m away from a road

Table 6. Wildlife habitat data formerly collected by USFS in Pisgah National Forest.

Parameter	Categories (Code)	Notes
Understory Community	Mountain laurel-blueberry (2)	*Kalmia latifolia*, *Vaccinium* spp.
	Blueberry-huckleberry-dogwood (4)	*Vaccinium* spp., *Cornus florida*
	Dogwood-maple-sassafrass (5)	*C. florida*, *Acer rubrum*, *Sassafras albidum*
	Upland hardwood (6)	Upland hardwood reproduction
	Cove hardwood (7)	Cove hardwood reproduction
	Rhododendron-hydrangea-maple leaf (8)	*Rhododendron* spp., *Hydrangea* spp., *Viburnum acerifolium*
	Sparse or absent (9)	
Understory Density	Sparse	
	Medium	
	Dense	
Soft mast	Dogwood (1)	*C. florida*
	Gum (2)	*Nyssa sylvatica*
	Serviceberry (3)	*Amelanchier arborea*
	Grape (4)	*Vitus* spp.
	Hawthorne (5)	*Cretaegus* spp.
	Cucumber (7)	*Magnolia accuminata*
	Cherry (8)	*Prunus serotina*

Table 6 (Continued)

Parameter	Categories (Code)	Notes
Soft mast Variety	No (0)	Less than 2 of above species
	Yes (1)	3 or more of above species
Soft mast Abundance	Little (0)	
	Some (1)	
	Abundant (2)	
Hard mast Basal Area	% to nearest 10%	See condition codes Table 4, page 32.
Hard mast lbs./acre	Lbs./acre to nearest 1/10 lb.	Calculated from table cross-referencing condition with forest cover type (USFS 1971)

Table 7. Parameterization of USFS Wildlife data for regression analysis, Compartments 57, 58, 60, and 72 in Harmon Den, Pisgah National Forest, North Carolina.

Parameter	Codes (Table 6)	Values for Regression Analysis	Explanation
Hard mast basal area		Direct %	
Hard mast lbs./acre		Direct lbs./acre	
Soft mast species	1,2	1	Ranked in order of as-
	3	3	assumed importance to
	4,5	4	bears. Based on
	8	5	Beeman & Pelton 1980.
	7	2	
Soft mast Variety	0	0	Less than 3 of above sps.
	1	1	3 or more of above sps.
Soft mast abundance	0	0	Little
	1	1	Some
	2	2	Abundant
Understory Food Potential	5,8,9	0	Ranked in order of as-
	5,7	1	sumed food potential
	2,4	2	based on understory community.
Understory Cover Potential	9	0	Ranked in order of as-
	4,5,6,7	1	sumed amounts of escape
	2,8	2	cover in understory community.
Understory Density	0	0	Sparse
	1	1	Medium
	2	2	Dense

in a heath thicket. Quigley (1982) acknowledged that apparent preference or avoidance of a specific feature such as a road or trail may be due in large part to the characteristics of the surrounding habitat.

Roads may in fact be used by bears as travel routes, and soft mast produced along road margins may be a valuable summer food source. Indeed the amount of area actually occupied by roads, even in an area such as Harmon Den, is small, so that the types of spatial techniques used to analyze other habitat features (forest cover type, stand age, etc.) are probably inappropriate for determining the effects of roads on habitat use.

In all studies where bears were said to avoid roads the avoidance was thought to be due to the human activity associated with roads rather than any specific effect that roads have on the biological quality of the habitat. Hunting is a particular human activity that may cause bears to learn to avoid roads. Collins (1983) found that 73% of the bears killed by hunters in Western North Carolina between 1975 and 1980 were shot less than 1.6k (1 mile) from a road, with 39% being shot within 400m of a road. Four-wheel drive vehicles and citizen band radios are standard equipment for the modern bear hunter, so that roads are indeed perilous places for bears. Typically, the hunters will drive along the roads slowly with a "strike dog" on the back or hood of the vehicle, searching for a place where a bear has recently crossed. Thus it may be that analyzing bear travel patterns with respect to roads will give a better indication of the effect of roads on habitat use than the standard spatial techniques.

The analysis used in this study starts with the assumption that if bears are indifferent to roads they will cross roads in direct proportion to the density of roads in their home ranges. Graphically we would expect the relationship between road density and road crossings to be a straight line passing through the origin with a positive slope (Figure 3). If high road densities have an inhibitory effect on bear movement we would expect the proportional relationship between road density and road crossings to be less at higher densities than at lower densities, that is, the slope of the line will decrease at high density. The line could either be 2-segmented or approach a certain number of crossings asymptotically (Figure 4).

For each radio collared bear's set of locations the minimum number of times the animal crossed a road was determined by sequentially plotting the locations on a USFS transportation map. Roads were classified according to the scheme in Table 5 (page 33), i.e., unrestricted improved, unrestricted 4-wheel drive, restricted-access improved (collector logging roads), and permanently closed or abandoned. Because the number of locations obtained for each animal varied, the minimum number of road crossings was divided by the total number of locations for each animal to arrive at an index of road crossing frequency. This index was then plotted

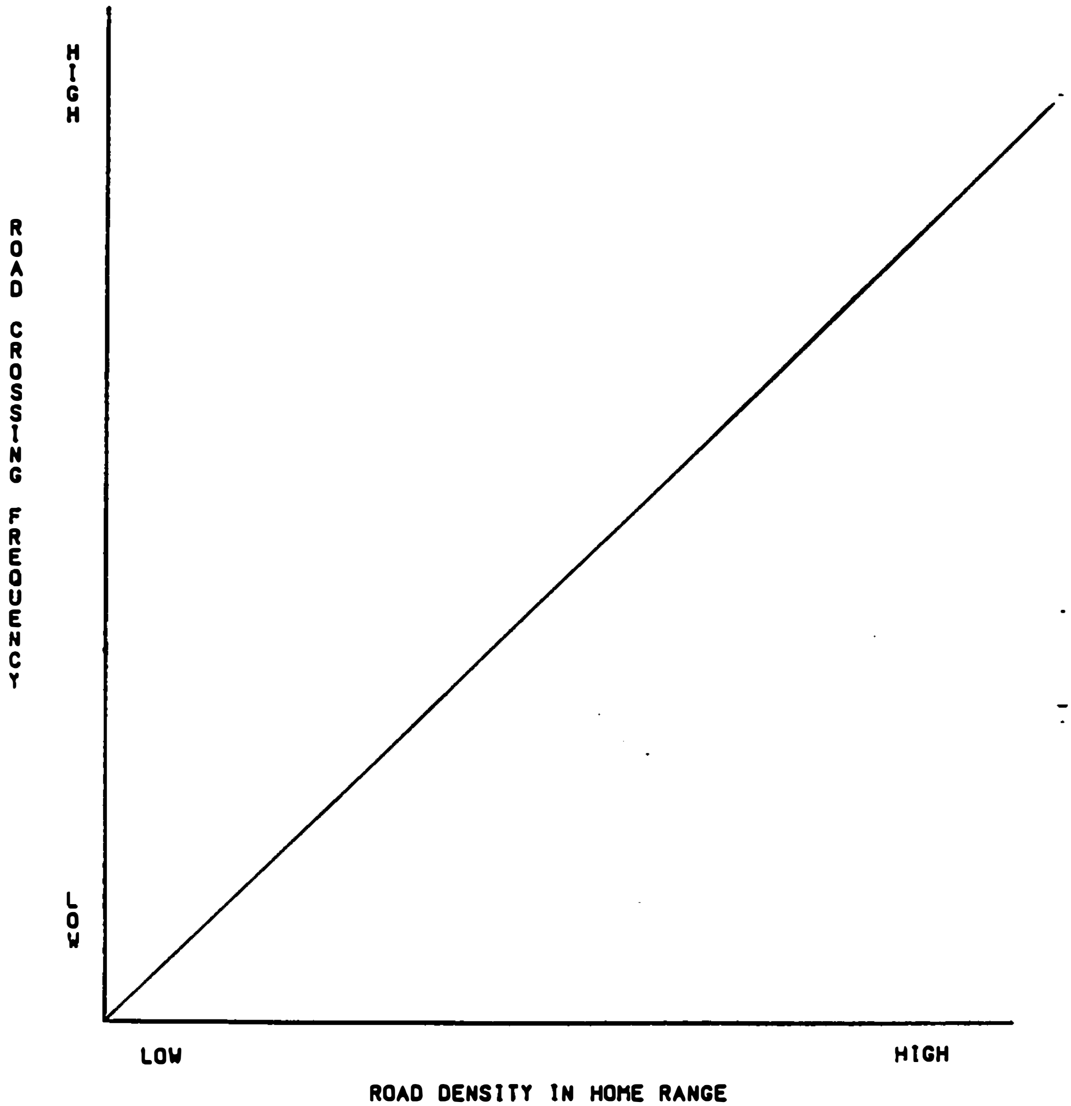

Figure 3. Hypothetical relationship between road crossing frequency and road density if high road densities do not restrict bear movements relative to low road densities.

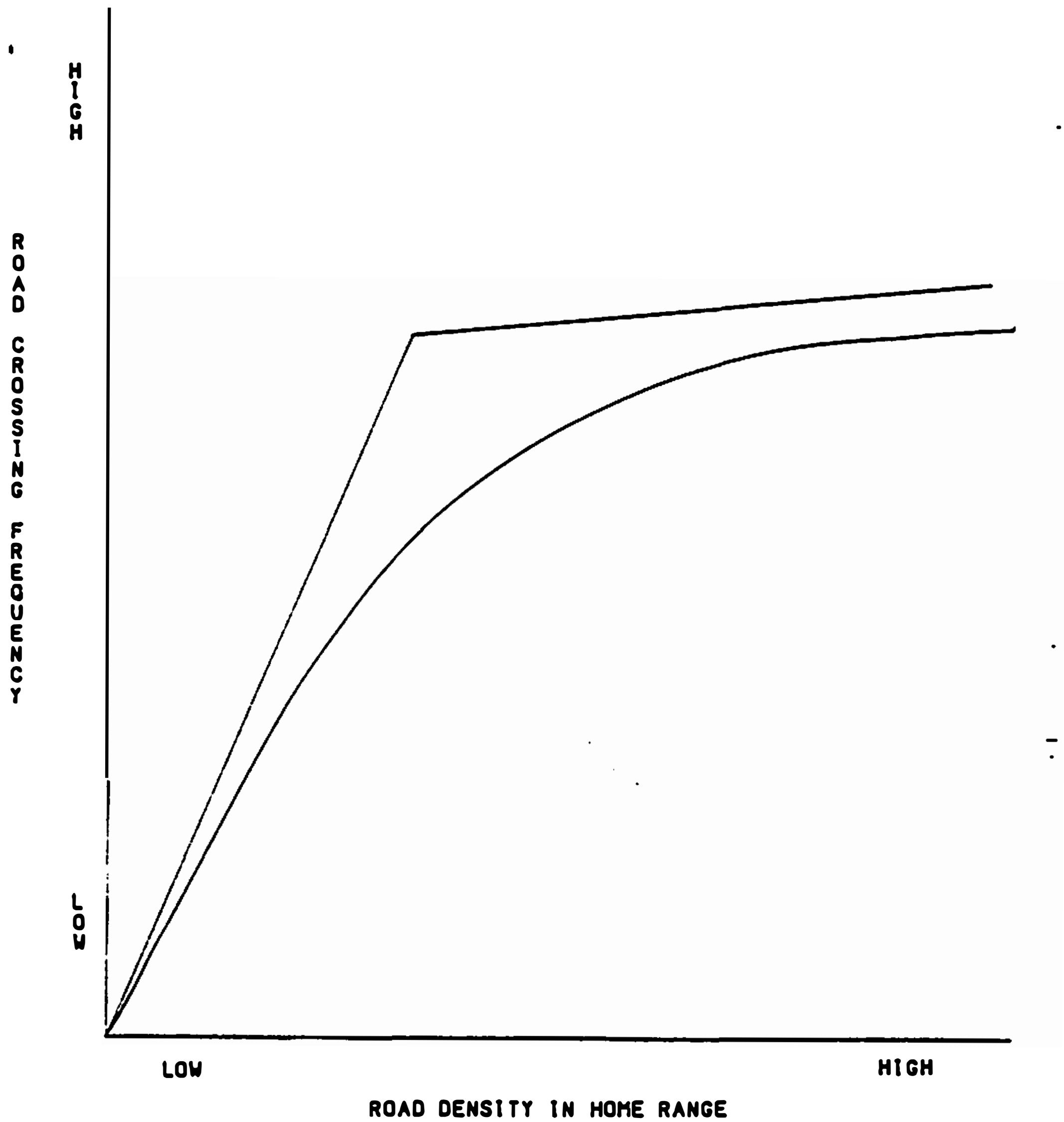

Figure 4. Hypothetical relationship between road crossing frequency and road density if high road densities do restrict bear movements relative to low road densities.

against the density of roads for each home range, and a line was fitted to the set of points. This line was then compared to the theoretical lines in Figures 3 and 4.

IV. RESULTS AND DISCUSSION

Trapping

Twenty-five captures involving 21 individual bears were made in 687 trap nights during 1982 and 1983 (Table 8). Captured animals included 13 females (11 were adults at time of capture) and 8 males (3 were adults at time of capture). Six traps were stolen from Long Arm Mountain on 17 June 1983; trapping efforts on the TMS were suspended after that. Physical data on captured animals are summarized in Table 9.

Telemetry

Tests of directional accuracy of ground telemetry were made using stationary transmitters in June 1982. These tests indicated that an arc of ± 7.1° used to plot error polygons would yield an average 94% confidence on locations obtained from ground triangulation. The mean size of error polygons calculated with this confidence was 23.8 ha. The above may seem like a large amount of error, but it should be noted that the majority of error polygons were substantially smaller than this, the average was increased by the presence of relatively few very large polygons. In any case, the average error polygon size of 23.8 ha is on the same scale as the average stand size of 19.5 ha. Most polygons overlapped more than one stand; in these cases the fraction of the error polygon included in each stand was estimated and recorded.

Table 8. Summary of trapping success on black bears, Harmon Den and Twelve Mile Strip, Pisgah National Forest, North Carolina, 1982-1983.

Trapline Location	Dates Operated	Trap Nights	Bears Captured
Harmon Den Mountain	11 June 82- 29 June 82	65	1
	15 July 82 - 25 July 82	66	2
	6 June 83 - 18 June 83	63	2
Subtotal		194	5
Hurricane Ridge	29 June 82 - 11 July 82	71	4
	5 June 83 - 30 June 83	76	1 + 1 Recapture
	3 July 83 - 9 July 83	26	1
	14 Aug. 83 - 18 Aug. 83	19	0
	9 Sept. 83 - 21 Sept. 83	20	4 + 1 Recapture
Subtotal		212	10 + 2 Recaptures
Long Arm Mountain	24 July 82 - 6 Aug. 82	10	3 + 1 Recapture
	17 Aug. 82 - 21 Aug. 82	12	1 + 1 Recapture
	4 May 83 - 18 June 83	139	2
Subtotal		181	6 + 2 Recaptures
Subtotal 1982		244	11 + 2 Recaptures
Subtotal 1983		343	10 + 2 Recaptures
TOTAL		687	21 + 4 Recaptures

Table 9. Summary of data on captured bears, Harmon Den and Twelve Mile Strip, Pisgah National Forest, North Carolina, 1982-1983.

Ear Tag No.	Date of Capture	Sex[a]	Age at 1st Capture	Weight (Kg)	Trapline[b]	Notes
123 *	12 June 82	F	3 1/2	53	HD	Found dead 17 June 82. Probably drug related.
526 *	28 June 82	M	1 1/2	29	HR	Excellent condition
528 *	7 July 82	M	2-1/2	57	HR	
529 *	9 July 82	F	5 1/2	61	HR	Estrus. Recaptured 21 Sept. 83. Weight 66 kg.
530 *	9 July 82	M	1 1/2	34	HR	
531 *	20 July 82	F	1 1/2	14	HD	Poor condition. Recaptured 8 June 83. Wgt. 20 kg.
532 *	20 July 82	F	7 1/2	59	HD	Lactating.
534 *	24 July 82	F	8 1/2	50	LA	Recaptured 4 Aug. 82.
535 *	29 July 82	M	2 1/2	36	LA	
536 *	30 July 82	M	2 1/2	48	LA	Poor condition. Recaptured 21 Aug. 82.
538 *	6 Aug. 82	F	7 1/2	57	LA	Top 1/2 of left ear missing.
539 *	11 June 83	F	?	41	LA	Relocated from Clingmans Dome (GSMNP) to Little Cattaloochee by NPS 25 June 82.

Table 9 (Continued)

Ear Tag No.	Date of Capture	Sex[a]	Age at 1st Capture	Weight (Kg)	Trapline[b]	Notes
550 *	12 June 83	F	1 1/2	14	HD	
521 *	13 June 83	F	3 1/2	32	HR	Excellent body condition.
520 *	17 June 83	M	1 1/2	16	HD	
523 *	8 July 83	M	4 1/2	100	HR	Lower canines badly worn by uppers. Excellent body condition.
524 *	8 Sept. 83	F	7 1/2	50	HR	Lactating. 1 cub observed. Poor body condition.
549	9 Sept. 83	F	12 1/2	59	HR	Lactating. Excellent body condition.
628	13 Sept. 83	F	2 1/2	16	HR	Excellent condition.
427	13 Sept. 83	F	5 1/2	50	HR	First digit on right front paw missing.

*These bears were radio collared.

[a]M = Male, F = Female.

[b]HR = Hurricane Ridge, HD = Harmon Den Mountain, LA = Long Arm Mountain.

Eighteen bears (10 female, 8 male) were radio-collared. Thirteen hundred and ten locations were obtained on collared animals in the 2 years of the study; 317 of these were from aircraft. Trapping activities and vehicle problems prevented a strict adherence to the planned 20-hour sampling interval, but, except for a few weeks when sampling was impossible because of vehicle problems, the average sampling interval for the 7 female bears that accounted for nearly 70% of the locations was 25.1 hours (no locations on an individual animal were obtained less than 18 hours apart). The sampling interval on all but 2 male bears was much greater and more irregular because most males spent much of their time outside of the study area. Tracking success, calculated as the number of days an animal was located divided by the number of days tracking was attempted (Garshelis and Pelton 1981), ranged from 20% (male 522) to 98% (female 531). Attrition through hunting was great; only 2 animals provided information for the entire duration of the study. Radio tracking success and eventual fates of the 18 collared bears are described in Figure 5.

Home Ranges

Collected data justified the construction of 39 seasonal ranges, including 10 male summer ranges, 8 male fall ranges, 11 female summer ranges, and 10 female fall ranges. At least 10 locations were used in the construction of each range. Average home range sizes, calculated from convex polygons, were as follows (given in hectares, with standard deviations):

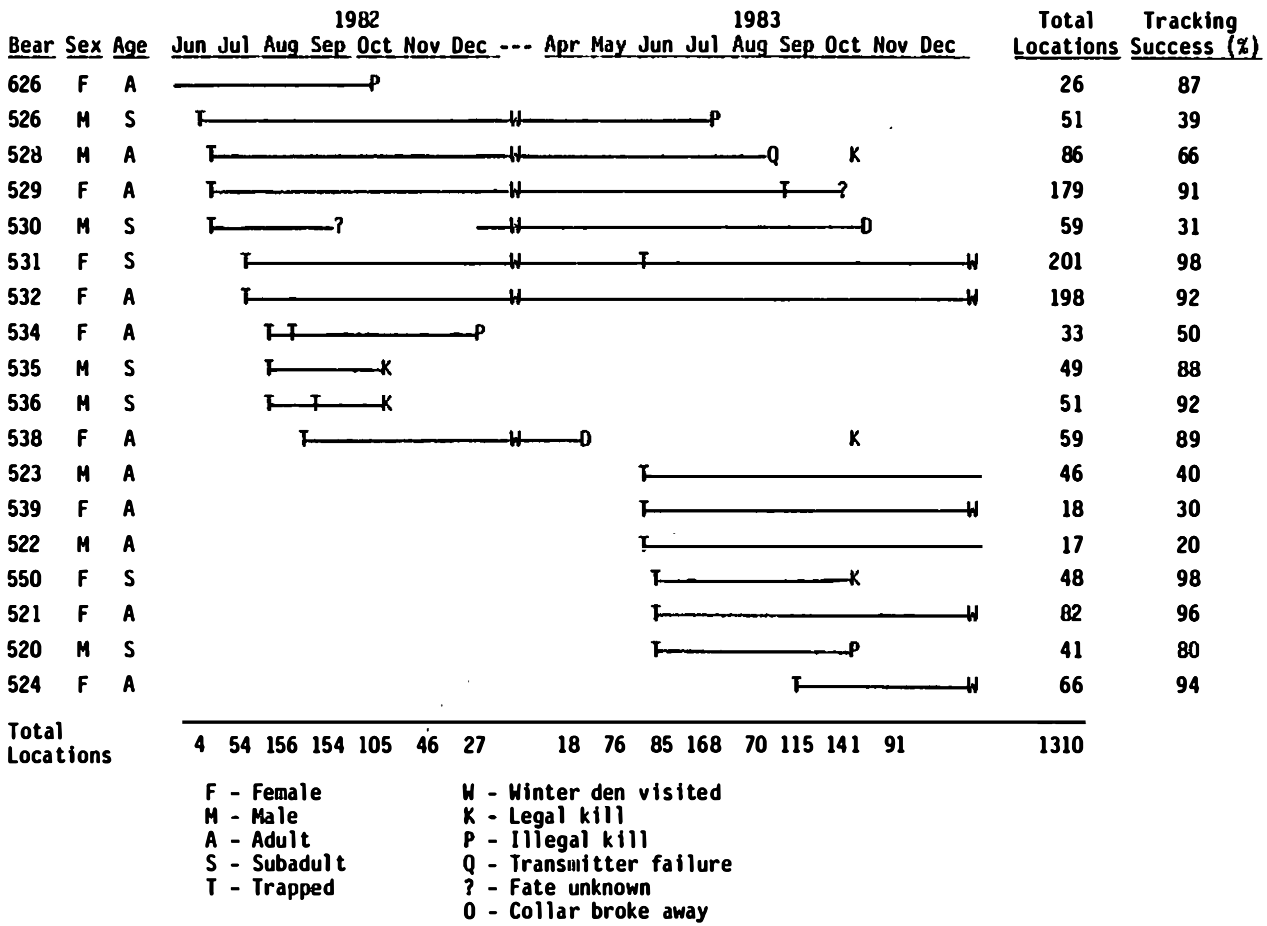

Figure 5. Duration of radio tracking, number of locations, and tracking success for radio collared bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983.

	Summer	Fall
Male	3,205 ± 4,374	6,931 ± 4,770
Female	872 ± 480	1,712 ± 761

In all cases these are larger than the home ranges given for bears in other parts of the southern Appalachians (Garshelis and Pelton 1981, Quigley 1982, Villarubia 1982, Carr 1983). The almost universally reported relationship between male and female range size held however; male ranges were significantly larger ($p \leq 0.1$). Social factors, particularly the low male-parental investment in offspring which would make promiscuity advantageous, as well as larger body size likely contribute to the larger size of male ranges (Rogers 1977, Harestad and Bunnel 1979).

Extensive overlap of home ranges was observed (Figures 6 and 7). On Harmon Den only the exceptionally small home range of a yearling female did not overlap with the synchronic ranges of all other bears. On the TMS all synchronic home ranges overlapped except for the fall 1982 range of an adult female that moved out of the study area. Little overlap was observed between ranges on Harmon Den and the TMS--this relationship will be discussed later.

Seasonal differences. There was a significant increase in range size between summer and fall for females ($p \leq .01$) and a borderline-significant increase for males ($p = .15$). This was true despite the slight reduction in range area from summer to fall exhibited by 3 females (Female 532 in 1983, Female 529 in 1983, and Female 521

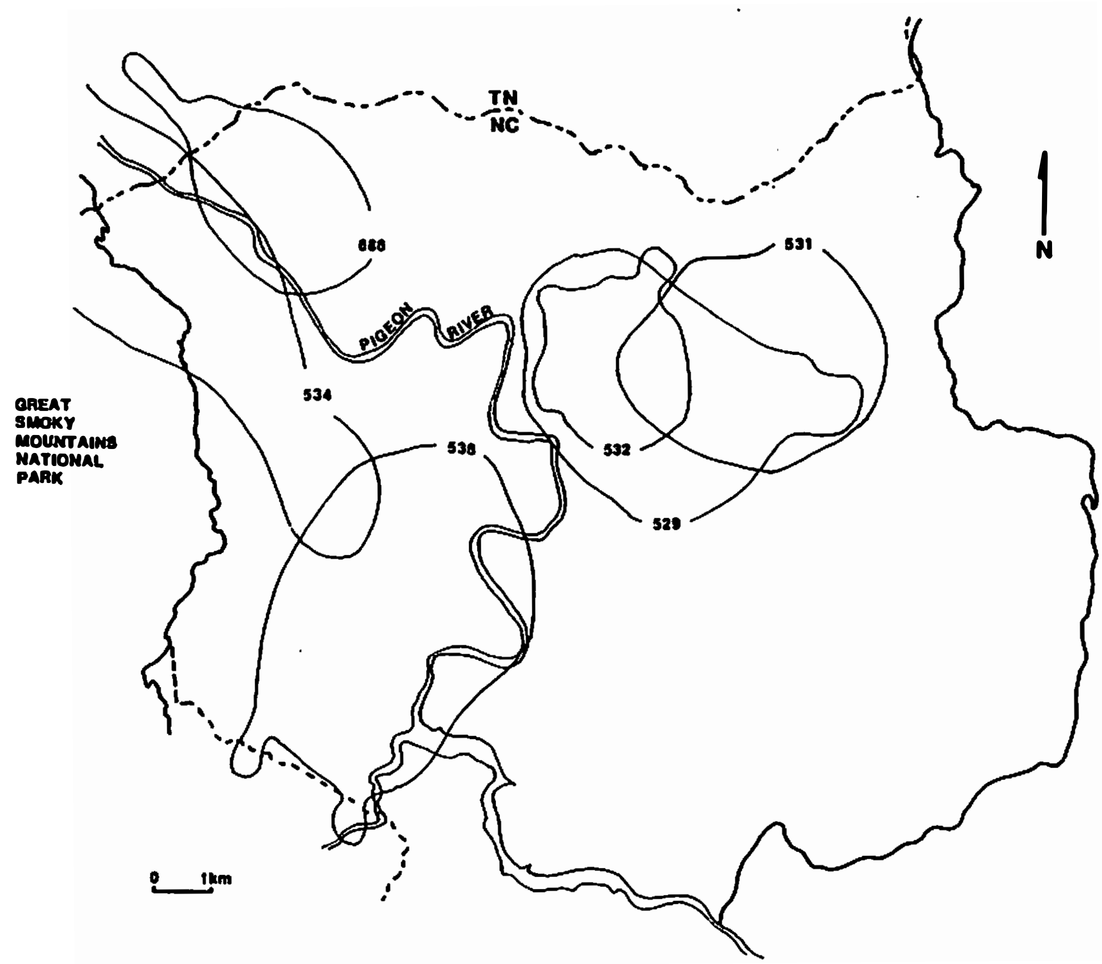

Figure 6. Annual home range overlap of radio collared female bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982. Home range boundaries drawn at 95th percentile of harmonic mean values for each animal's locations.

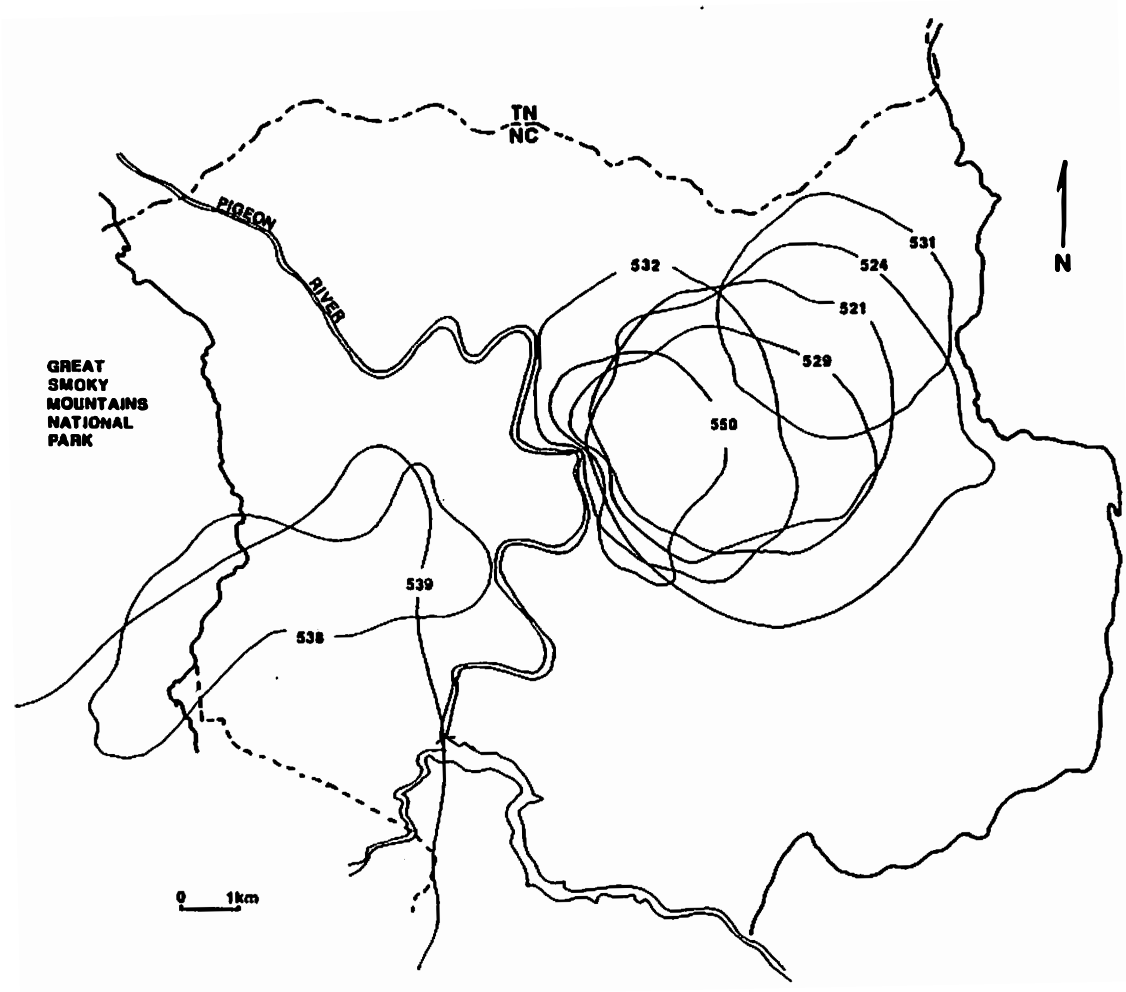

Figure 7. Annual home range overlap of radio collared female bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1983. Home range boundaries drawn at 95th percentile of harmonic mean values for each animal's locations.

in 1983). Since the data for these 3 animals are more complete than the data for most of the others, the general conclusion that range size increases in the fall is suspect. The observed increase may be in part an artifact of how the data were collected, tracking success for far-ranging animals increased in the fall due to increased amount of aerial tracking.

Whatever seasonal changes there were in home range size were apparently not accompanied by geographic shifts in activity centers. Table 10 compares seasonal movements in the location of the harmonic center of activity (Dixon and Chapman 1980) for each animal. The inter-season differences for each year are not significantly different ($p \geq .05$) from the inter-annual distances for each season, suggesting that geographic changes in seasonal activity centers are not great. Again, however, this conclusion is somewhat suspect because three far-ranging bears (Female 534, Male 530, Male 525), whose movements may have been seasonally mediated, could not be included in the analysis because data were so sparse. The movements of these animals are discussed in a later section.

Garshelis and Pelton (1981), Carr (1983), and Garris (1983) all noted significant changes in the location of activity centers with season for bears in the southern Appalachians, as did Reynolds and Beechum (1980) for black bears in Idaho. (All of these studies used arithmetic centers rather than harmonic centers.) In all cases the geographic shifts in activity centers were related to the patchy distribution of fall food sources, particularly oaks. Essentially

Table 10. Distances between seasonal activity centers[a] of individual black bears on Harmon Den and Twelve Mile Strip, Pisgah National Forest, North Carolina, 1982 and 1983.

From:	To: Fall 1982	Summer 1983	Fall 1983
FEMALE			
Summer 1982	9.6±2.5(4)	9.6±3.1(3)	
Fall 1982		11.8±9.3(3)	19.2±11.2(3)
Summer 1983			13.5± 8.3(5)
MALE			
Summer 1982	26.6±12.5(4)	12.7±9.3(2)	
Fall 1982		6.3± (1)	--- (0)
Summer 1983			40.6±32.0(2)

[a]Distances given in hundreds of meters ± 1 standard deviation. Number of pairs of seasonal ranges of an individual bear used in analysis is given in parentheses.

85% of the Harmon Den-TMS study area is covered in oak types, so that distribution of oaks is not patchy (although production of acorns may be), and seasonal shifts in activity center would not be expected purely on that basis.

Notable Movements

While the Harmon Den-TMS bear population did little moving as a whole, the movements of several individuals are worthy of examination. Figure 8 illustrates the following discussion. All 3 of the subadult males in Harmon Den made dramatic movements in the fall of their yearling years. Yearling Male 526 moved from the study area to near Round Mountain, Tennessee, a straight line distance of nearly 13 km, in August 1982. He remained there through the winter, denning in a clearcut on private land in Lamb Gulf. Spring 1983 found him back in the study area, and his movements were localized in the area of his 1982 summer range until late June. On 30 June 1983, he was located back in the Round Mountain area where he remained until being poached in late July 1983.

Male 520 was collared as a yearling on Harmon Den Mountain in June 1983. In late August he also moved to Round Mountain, Tennessee, but within 2 weeks was back in the study area on Ground Hog Creek. He made a short foray onto the TMS, but returned to Harmon Den Mountain where he remained until early October, when he moved to the Snowbird Mountain area on the Tennessee state line. On 26 October 1983 he was poached at the mouth of Ground Hog Creek.

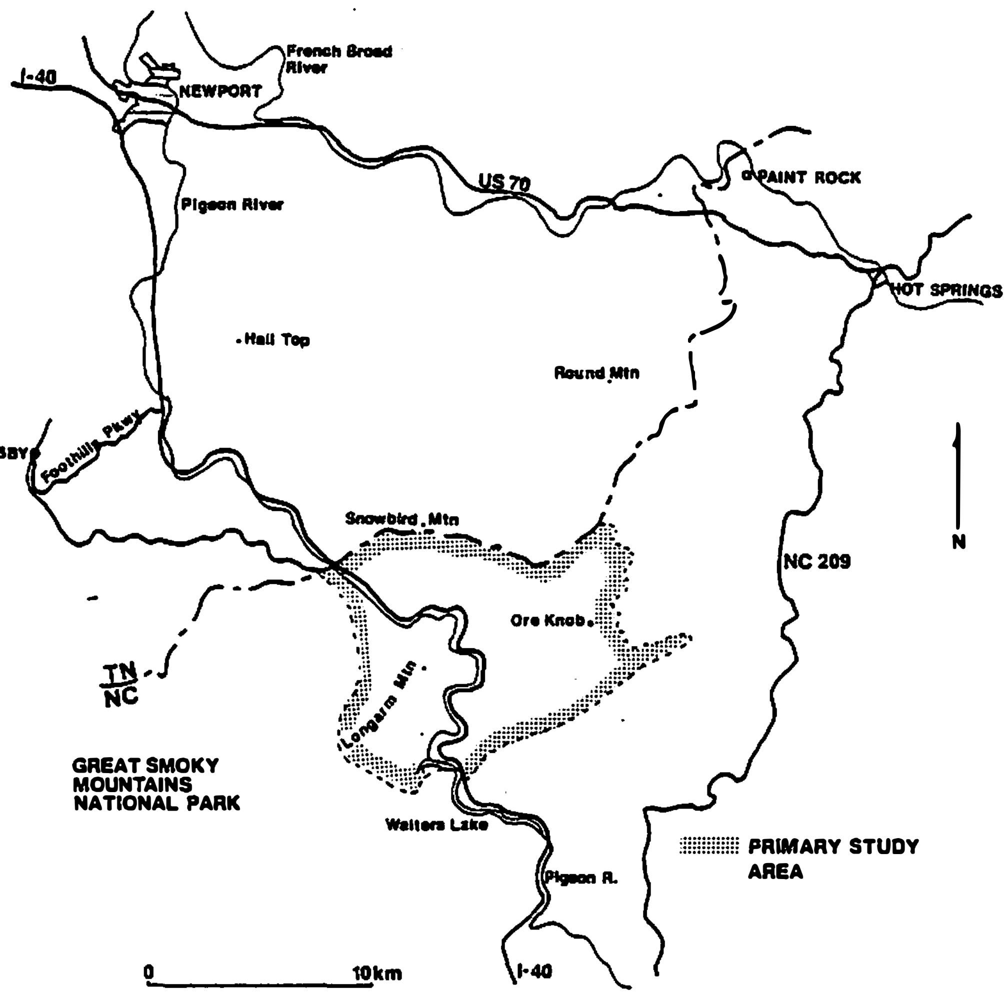

Figure 8. Area of long distance movements by bears radio collared on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983. Shows locations of places named in text.

Male 530 was collared as a yearling on Hurricane Ridge in July, 1982. His home range remained relatively small through the summer but in early October he moved into the central part of Harmon Den near Hickory Ridge. He left the study area for parts unknown in early November, and I could not locate him from the air or ground. He returned to Harmon Den in the winter, however, and denned near Hurricane Gap in his summer range. He remained in the study area until July 1983 when he also moved to the Round Mountain, Tennessee, area. In early September he moved even farther north and east, crossing the French Broad River, but 1 week later he was located back on Round Mountain. In October he again moved east, to Shutin Creek near Paint Rock, North Carolina, a distance of approximately 8 km (about 20 km from his original summer range) where he remained until his break-away collar fell off in November, 1983.

The 3 adult males followed during the study also made long movements (in fact, Male 523 used the Round Mountain and Snowbird Mountain areas), but the movements of these 3 subadults are in contrast to the very restricted size of their yearling summer ranges. Male 526's range increased from 422 ha in summer 1982 to 12,755 ha in fall 1982, to 14,400 ha in summer 1983. Male 530's range increased from 893 ha in Summer 1982 to 16,242 ha in Summer 1983 (size of his Fall 1982 range is unknown). Male 520's range increased from 471 ha in Summer 1983 to 14,233 ha in Fall 1983. The subadult male (535) collared on TMS also exhibited an expanded home range during the fall of his yearling year, but it was not nearly as dramatic

(124 ha in Summer 1982 to 1543 ha in Fall 1982) and was not accompanied by a geographic shift.

Movements similar to those of the 3 Harmon Den yearlings have been reported frequently (Rogers 1977, Garshelis and Pelton 1981, Quigley 1982, Koch 1983), but are not fully understood. Such movements are often thought to be related to seasonal feeding behavior and location of fall food sources. At first consideration this idea is attractive in this case because the movements seem to be localized to the Round Mountain area; however, Males 520 and 525 started their movements in August, well before acorns were ripe, and Male 520 returned to the study area in October. Additionally, the other segments of the population showed no propensity for such food-related movements. Rogers (1979) interpreted some of the similar movements he observed as dispersal behavior, claiming that young females tend to establish adult home ranges coincident with their natal ranges while young males establish adult ranges outside of their natal ranges. Dispersal seems the likely explanation for the behavior of the 3 yearling males in this study, especially when compared to the 2 yearling females, both of which exhibited only slight range expansions with increasing age. The localization of movements may be a reflection of bear population density more than anything else. Lamb Gulf is suitable habitat for bears but hunting and poaching pressure is severe so density is low, inviting dispersal from more heavily populated areas such as Harmon Den. Bear density on TMS is low, perhaps explaining the lack of such possible dispersal behavior by Male 535.

Besides the movements of the yearling males, the movements of 1 adult female are notable also. Female 534 was captured in late July 1982, and recaptured in early August 1982, on the TMS. Her movements were restricted until mid-September when she moved northwest onto the Cherokee National Forest near Hall Top fire tower, a distance of 21 km, crossing I-40 in the process. In October she crossed I-40 again, moving southwest 9 km onto National Park Service land along the Foothills Parkway near Cosby, Tennessee. The Foothills Parkway is a small island of bear habitat (approximately 1000 ha) surrounded on 3 sides by a rural human population. The bear remained along the Foothills Parkway until late December when she apparently started back towards the TMS. She was poached in GSMNP near Tennessee Route 32 on 24 December 1982.

Being 8 years old at the time of capture, the movements of this female cannot be considered "dispersal" in the usual sense of a juvenile animal establishing a new adult range. The public land surrounding the Foothills Parkway is mature oak-pine forest, the private land in the area contains several apple orchards and grain fields, so that the movements of this particular animal may in fact have been food-related.

In the context of unusual movements it is pertinent to discuss I-40 and the Pigeon River gorge which appeared to form a strong but not complete barrier to bear movements. As previously mentioned, Harmon Den and TMS home ranges overlapped very little. In all, only 7 collared bears were observed to cross I-40 a total of 15 times, and only 2 animals crossed and recrossed more than once during the study, this including the movements of the 4 bears just discussed. Movement across I-40 occurs but it is apparently dangerous--3 uncollared bears were killed in collisions with motor vehicles on I-40 between Walters Lake and Waterville during the study. Local bear hunters claim that bears use the ridge above the tunnel at Ground Hog Creek to cross between the areas, and a location west of this tunnel is a frequently used hunting stand. Indeed, 2 of the collared animals were shot near the tunnel.

Use of Individual CISC Categories

One thousand and twenty of the 1310 radio locations were on USFS land and so were used in the following analyses. Table 11 compares the amount of each CISC category (Table 4, page 32) used by bears to the amounts available; significance was determined after Neu et al. (1974).

Cover type. Both males and females showed an avoidance or indifference to the softwood and mixed hardwood-softwood types throughout the year. Both sexes also showed a preference in the summer for brush areas--these are mostly transmission line easements or old fields providing thick cover and containing concentrations of soft mast species, particularly blackberries (*Rubus* spp.) and pokeberry (*Phytolacca americana*). Males showed a summer preference for the Yellow Poplar-Oak stands, and both sexes preferred these stands in the fall. Garshelis and Pelton (1981), Quigley (1982), Villarubia

Table 11. Habitat use by black bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, North Carolina, 1982-1983.

Category	% of Area	% Radio Locations in Summer	Significance[a]	Annual Difference 1982-1983[b]	% Radio Locations in Fall	Significance[a]	Annual Difference 1982-1983[b]
FEMALE							
FOREST COVER TYPE							
Softwood types	9.3	2.9	-		4.8	-	
Hardwood/Softwood types	6.2	4.7	0		4.2	0	
Yellow Poplar	7.4	8.6	0		6.6	0	
Chestnut Oak	5.5	3.2	0		2.5	-	
White Oak-Red Oak-Hickory	41.2	40.2	0		41.6	0	
Yellow Poplar-White Oak-No. Red Oak	25.7	33.0	+		35.2	+	
Scarlet Oak	4.6	6.7	0		5.0	0	
Brush	0.1	0.6	+		0.1	0	
MANAGEMENT TYPE							
White Pine	16.9	8.2	-		5.1	-	
Chestnut Oak	0.1	0.1	0		0.8	0	
White Oak-Red Oak-Hickory	49.0	52.7	0		50.0	0	- +
Yellow Poplar-White Oak-No. Red Oak	37.5	38.4	0		44.0	0	
Brush Species	0.1	0.6	+		0.1	0	
STAND AGE							
≤ 9 years	3.4	6.0	+		1.5	0	
10-29 years	5.4	2.4	-		6.5	0	
30-49 years	14.7	5.4	-		5.6	-	
50-69 years	62.5	82.2	+		77.0	+	
70-89 years	7.7	5.2	0		8.1	0	
90+ years	6.3	2.8	-	0	1.3	-	
OPERABILITY							
Inoperable	54.3	48.8	0		42.8	-	0
Poletimber	20.0	14.7	-	0	18.3	0	
Sawtimber	25.7	36.5	+		38.9	+	

Table 11 (Continued)

Category	% of Area	% Radio Locations in Summer	Significance[a]	Annual Difference 1982-1983[b]	% Radio Locations in Fall	Significance[a]	Annual Difference 1982-1983[b]
<u>CONDITION</u>							
In regeneration	6.3	4.3	0		6.4	0	
Low stem density	44.7	42.3	0	+	35.2	-	
High stem density	49.0	52.7	0		58.3	+	
<u>SITE INDEX</u>							
0	3.4	0.6	-		0.1	-	
40	0.1	0.1	0		0.8	0	
50	2.2	2.0	0		0.8	0	
60	3.7	3.4	0		3.5	0	
70	32.9	17.9	-		17.1	-	
80	22.9	50.2	+		47.6	+	
90	9.7	11.3	0		13.2	0	
100	8.0	4.0	-		3.5	-	
110	9.8	6.6	0		9.3	0	
120	0.8	3.6	0		2.7	0	
130	0.5	0.2	0		1.5	0	
<u>MAST CAPABILITY</u>							
0	8.5	2.9	-		6.5	0	-
1	1.1	2.0	0		2.4	0	
2	18.1	14.8	0		14.1	0	
3	72.3	80.2	+		77.0	+	
<u>METHOD OF CUT</u>							
No cuts	54.3	48.7	0		42.8	0	
Clear cuts	17.8	17.2	0		23.0	0	
Thin	27.9	34.1	0		34.1	0	
<u>SIZE OF STAND</u>							
1-60 acres	42.1	66.3	+		61.9	+	
61-155 acres	36.9	19.2	-		22.3	-	
155 acres	21.0	14.5	-		15.8	-	0

Table 11 (Continued)

Category	% of Area	% Radio Locations in Summer	Significance[a]	Annual Difference 1982-1983[b]	% Radio Locations in Fall	Significance[a]	Annual Difference 1982-1983[b]
MALE							
FOREST COVER TYPE							
Softwood types	9.3	11.4	0		9.2	0	
Hardwood/Softwood types	6.2	3.6	-		9.3	0	+
Yellow Poplar	7.4	5.3	0		5.4	0	
Chestnut Oak	5.5	7.3	0		8.0	+	-
White Oak-Red Oak-Hickory	41.2	44.1	0		17.7	-	
Yellow Poplar-White Oak-No. Red Oak	25.7	29.0	0	+	46.9	+	
Scarlet Oak	4.6	9.5	0	+	3.5	0	
Brush	0.1	0.8	+		0.0	0	
MANAGEMENT TYPE							
White Pine	16.9	10.6	-		17.7	0	-
Chestnut Oak	0.1	1.1	0		0.3	0	+
White Oak-Red Oak-Hickory	49.0	52.4	0		29.7	-	+
Yellow Poplar-White Oak-							-
No. Red Oak	37.5	49.0	0		52.3	+	
Brush	0.1	1.0	0		0.0	0	
STAND AGE							
≤ 9 years	3.4	6.1	+		3.0	0	
10-29 years	5.4	0.1	-		2.8	-	
30-49 years	14.7	6.6	-		12.4	0	
50-69 years	62.5	80.0	+		53.7	0	- +
70-89 years	7.7	5.9	0		15.6	+	-
90+ years	6.3	1.3	-		12.4	+	0
OPERABILITY							
Inoperable	54.3	54.3	0	+	37.7	-	
Poletimber	20.0	18.7	0	-	11.0	-	
Sawtimber	25.7	27.1	0		57.3	+	

Table 11 (Continued)

Category	% of Area	% Radio Locations in Summer	Significance[a]	Annual Difference 1982-1983[b]	% Radio Locations in Fall	Significance[a]	Annual Difference 1982-1983[b]
CONDITION							
In regeneration	6.3	4.3	0		3.0	0	
Low stem density	44.7	42.9	0	-	3.0	0	
High stem density	49.0	51.8	0	+	63.5	+	
SITE INDEX							
0	3.4	0.6	-	0	0.0	-	
40	0.1	1.1	0		0.3	0	
50	2.2	0.8	0		1.0	0	
60	3.7	2.7	0		3.9	0	
70	32.9	34.3	0		19.6	-	
80	27.9	37.6	+		39.0	+	
90	9.2	15.7	+		17.5	+	
100	9.0	4.2	-		1.3	-	
110	9.8	2.7	-		13.0	+	-
120	0.8	0.0	0		2.3	0	
130	0.5	0.0	0		2.1	0	
MAST CAPABILITY							
0	8.5	6.1	0		4.6	0	
1	1.1	0.7	0		2.6	0	
2	18.1	13.2	0		12.3	0	+
3	72.3	80.0	+	0	79.5	+	-
METHOD OF CUT							
No cuts	54.3	54.3	0		43.7	0	
Clear cuts	27.9	12.5	-		25.8	0	
Thin	17.8	33.2	+		30.5	+	
SIZE OF STAND							
1-60 acres	42.1	53.1	+		54.3	+	
61-155 acres	36.9	30.7	0		36.4	0	
155 acres	21.0	16.2	0	-	9.3	-	

[a]0 = used in proportion to availability, $p \leq .10$
+ = used in greater proportion than available, $p \leq .10$.
- = used in less proportion than available, $p \leq .10$.

[b]If the significance for 1982 or 1983 individually is different from the significance for 2 years combined, the individual significance is noted in the appropriate column.

(1982), Carr (1983) and Garris (1983) have all documented strong fall preferences for mast areas by bears in the southern Appalachians, so that the apparent indifference (females) or avoidance (males) of the White Oak-Red Oak-Hickory type in this study was unexpected. The age distribution of White Oak-Red Oak-Hickory and Yellow Poplar-Oak stands in Harmon Den are essentially the same, so that the preference for the Yellow Poplar-Oak stands is most likely not due to a preponderance of Yellow Poplar-Oak stands in the more productive age classes. Mast production in the Yellow Poplar-Oak stands may have been higher, however, for other unknown reasons (weather?); NCWRC 1983 mast survey data for Harmon Den showed a generally higher number of acorns at sample sites in the Yellow Poplar-Oak type than at sites in the White Oak-Red Oak-Hickory type. Such data were not available for 1982, but personal observations showed the 1982 mast crop to be a nearly complete failure, perhaps causing bears to rely on soft mast species, such as cherry (*Prunus serotina*) or serviceberry (*Amelanchier arborea*), which are more abundant in the Yellow Poplar-Oak type (Golden 1981). It is also entirely possible that factors other than food may be responsible for the observed preferences, and that mast production in the Yellow Poplar-Oak type, supplemented with occasional use of the other oak types, may provide adequate fall food supplies.

Management type. Except for males in the fall (and these data were conflicting between 2 years), the observed forest cover type utilization patterns disappear when management type is considered. There is a substantially larger area in the Yellow Poplar-Oak management type than in the in-place Yellow Poplar-Oak cover type, so that the differences may indicate that bears respond more to the vegetation in place than they do to particular site characteristics.

Stand age. In the summer, stands of less than 10 years old were preferred by both sexes. This is largely due to the availability of soft mast in clearcuts. Stands between 10 and 50 years old were avoided or used in proportion to their availability by both sexes throughout the year. Stands in the 50 to 70 year age class were preferred by both sexes throughout the year, except by males in fall 1982. The use of stands in this age class is especially notable because of the high availability of such stands, and probably represents a pronounced preference. Older stands were preferred by males in the fall but avoided or used in proportion to availability by females throughout the year, and males in the summer. The mast capability rating is essentially a reclassification of the stand age groups based on the relationship between age and mast production; the utilization seen in the age classification is reinforced by the utilization of the mast capability classes. Bears apparently prefer the most productive stands.

Site index. Females preferred stands with site indices of 80 throughout the year; males preferred stands with site indices of 80 or 90. Use of stands with site indices above or below this range seemed reduced, although the small amount of area with site index greater than 90 would make conclusions about high site indices suspect; there may be a general pattern of increased use with increased site index.

Stand condition. No differential use of condition classes was evident during the summer. Fall utilization was the same for both sexes--indifference to stands in regeneration or poor condition, an avoidance of established stands with low stem densities and a preference for stands with high stem densities.

Operability. Females apparently avoided poletimber stands in the summer and inoperable stands in the fall, while sawtimber stands were preferred throughout the year. Males were indifferent to operability in the summer, but used sawtimber stands heavily in the fall. There seems to be a general preference for stands with high basal areas.

Method of cut. Method of cut did not seem to affect females use of stands; males apparently preferred stands deemed unsuitable for clearcutting throughout the year.

Stand size. Both sexes used stands of 60 acres or less at the expense of larger stands. Small stand size is a consequence of clearcutting, and bears may be responding to the increased diversity of stand ages in these areas.

Modeling the Simultaneous Effects of Several Habitat Variables

While it is possible to discuss the effect of each habitat variable separately, a more realistic approach is to consider the simultaneous effect of several variables. The SAS (1979) "General Linear Models" procedure was used extensively in the following analyses. In all the following analyses the use of an individual stand by an individual bear is taken as one sample value of the dependent variable. Calculations were weighted by percentile value of the harmonic mean of distances to bear locations for each stand (Figures 9 and 10).

Forest cover type and stand age. The 2 most important characteristics affecting the physiognomy of a forest stand are the species composition and the age of that stand. The previous analyses of cover type and age individually indicate that both the successional stage of a stand and the dominant tree species may affect the suitability of the stand for bears. This is especially important when it is realized that for the first 20 years of a stand's life it may be dominated by species other than those named in the cover type name.

The results of a 2-way analysis of variance incorporating cover type and age as main effects are shown in Table 12. In general, age is found to be the significant effect in the summer, while age and cover type interact in the fall. This is in keeping with previous observations: during the summer very young stands are utilized because of their soft mast production and the species composition of the seedlings would likely be unimportant; hard mast

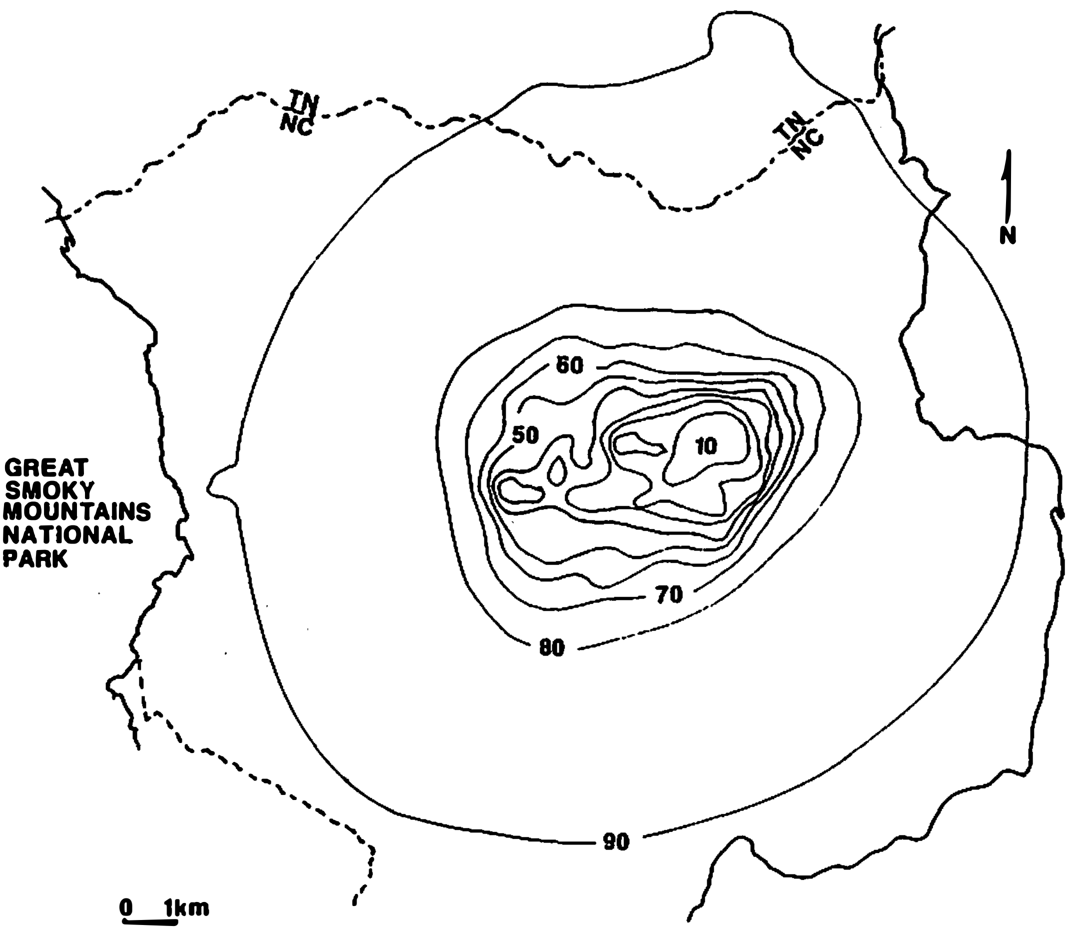

Figure 9. Contour map of harmonic mean values of all summer bear locations on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983. Contour lines encompass successive percentiles of harmonic mean values; contour interval is 10%.

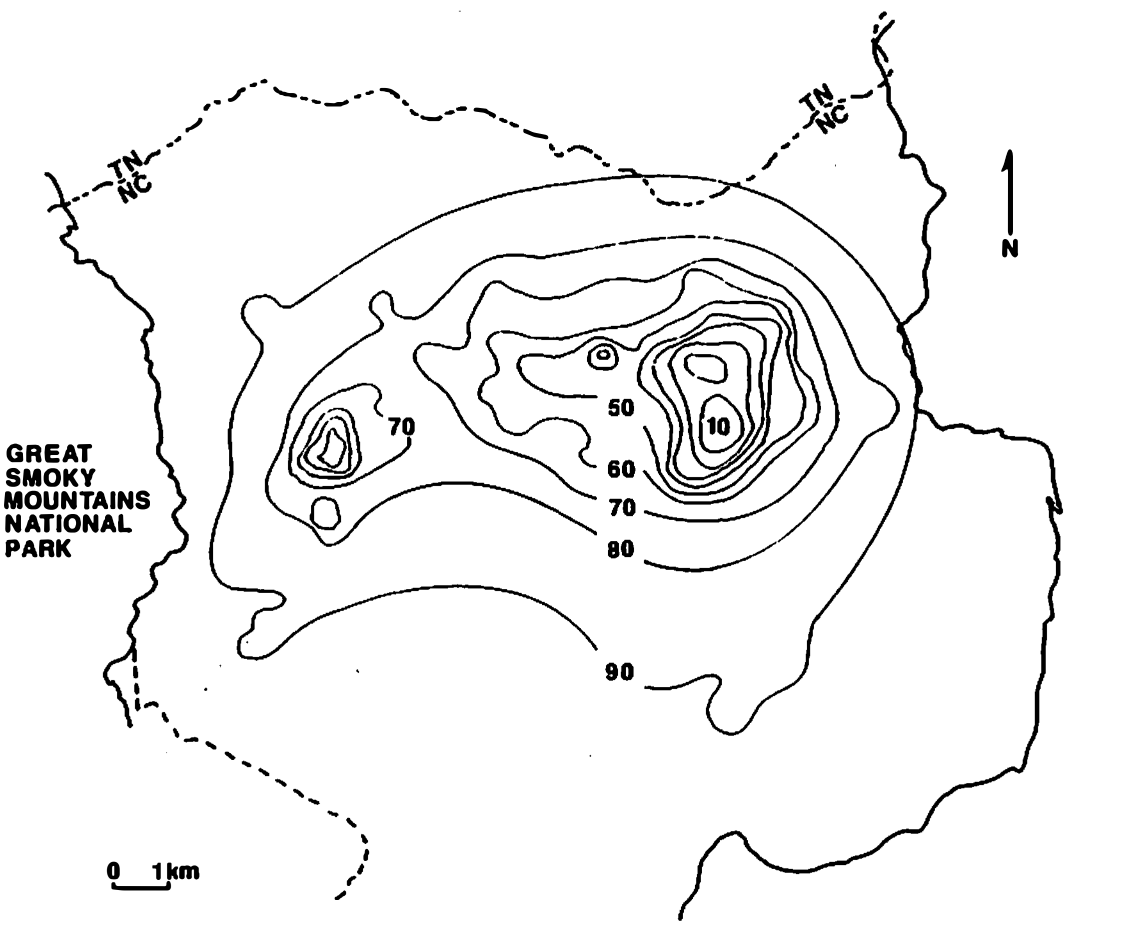

Figure 10. Contour map of harmonic mean values of all fall bear locations on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983. Contour lines encompass successive percentiles of harmonic mean values; contour interval is 10%.

Table 12. Effect of forest cover type and stand age on bear use of individual forest stands, Harmon Den and Twelve Mile Strip, Pisgah National Forest, North Carolina, 1982 and 1983, as determined by Analysis of Variance.

	Females				Males				Overall	
	Summer		Fall		Summer		Fall			
Effect	1982	1983	1982	1983	1982	1983	1982	1983	Summer	Fall
Cover Type[a] (6 d.f.)		*	*	*			*			*
Stand Age[b] (19 d.f.)	*	*	*	*			*		*	*
Cover x Age				*			*			*
Error degrees of freedom	245	466	199	646	161	264	273	127	1125	1364
R^2	.21	.15	.24	.14	.26	.17	.27	.27	.13	.16

[a]Cover types as in Table 4, page 30.

[b]5-year age classes.

*- indicates F significant at $p \leq .10$.

production is related both to species and tree age so that in the fall interaction between the 2 main effects is significant. The summer preference for stands aged 50 to 90 years (see Table 11, page 59) was apparently not related to the cover type of these stands. Additionally, the lack of any significant effects for males in the summer should be noted, a good indication that something apart from food, breeding instinct perhaps, influences male behavior in the summer. summer. Finally, the rather low R^2 values in each of the models also are noteworthy; there is still a large amount of variance in bear use of stands to be explained after the 2 most obvious variables are taken into account. Figures 14 through 20 (Appendices A-G) illustrate the relationship between age of stands used and the age of stands available for each forst cover type.

Multiple regression model. The 19 variables described in Tables 5 and 6 (pages 31 and 35, respectively) were regressed against bear use of individual stands (Table 13). Stands that none of the collared bears were ever located in were excluded from analysis. Results did not explain much of the observed variance; R^2 values are low and reasonable biological interpretations for some of the significant coefficient estimates are difficult to make. However, because models of this type would be useful in making management decisions, they are worthy of discussion. One encouraging point is that the sign of most of the coefficients appears to stay constant across the sex and seasonal models. Considering the CISC variables in the models, bear use

Table 13. Partial regression coefficient estimates and R^2 values for models of black bear habitat use using 19 CISC and derived variables.

Independent Variable[b]	Partial Regression Coefficient Estimates[a]			
	Females		Males	
	Summer	Fall	Summer	Fall
FCR	+	-1.4	+	-2.5
AGE	-	+	-	+ .3
SIT	+.13	+ .6	+	+ .2
CON	-7.11	-18.9	-	-
OPE	+	+	+	+
MOC	-	-5.3	-10.8	-1.9
BUL	+	+	-	-
ASP	-3.8	-3.4	-8.3	-3.4
MAS	+6.0	+2.9	+5.9	+
MGR	+	+1.0	+	-
TPD	-	+4.4	-	+
EFD	+10.5	+11.5	+22.8	+13.8
EAD	+	-	+13.0	+
EAR	-	-11.2	+	+
ELE	-	-	190.4	-
RD1	-	+ .3	-	-
RD2	-	-	-	-
RD3	+ .5	+ .5	+6.7	+ .2
RD4	-	-	+	+
R^{2c} (error degrees of freedom)	.14 (460)	.16 (642)	.19 (255)	.19 (113)

[a]For estimates significantly different from 0 at $p \leq .10$, the value of the estimate is given. For estimates not significantly different from 0, only the sign of the estimate is given. All coefficients x 10^3.

[b]Variable abbreviations: FCR=forest cover type rating, AGE=age of stand, SIT=site index, CON=stand condition, OPE=operability, MOC=method of cut, BUL=degree of broad use limitation, ASP=aspect, MAS=mast capability rating, MGR=management type rating, TPD=topographic diversity, EFD=forest cover type edge density, EAD=age edge diversity, EAR=edge to area ratio, ELE=elevation, RD1=unrestricted improved road density, RD2=open 4 wheel drive road density, RD3=restricted-access improved road density, RD4=abandoned road density. See Table 5 (page 31) and Table 6 (page 35) for explanation of variables.

[c]F values for all models significant at $p \leq .01$.

varied directly with site index and operability, and inversely with stand condition. Considering the topographic variables, bear use varied inversely with elevation and aspect (the more northerly the aspect, the lower the use by bears). Inter-stand diversity positively affected bear use; in particular, forest cover type diversity had a significant positive effect for both sexes throughout the year. For opportunistic feeders such as black bears, diversity probably improves habitat quality by decreasing the relative negative effect that the failure of individual food sources in a given season or area may have. Such protection may be especially important in light of the recent extirpation of chestnut (Castanea dentata), an unusually productive and reliable food source.

The density of restricted access improved roads had a significant positive effect on bear use in all the models. More than indicating a preference on the part of bears for logging roads, however, this relationship points out a strong but frequently ignored bias in radio telemetry studies; that is, the closer an animal is to the routes traveled by the investigator, the more likely that animal is to be located. The farther an animal gets from the receiver, the more difficult is the signal to pick up and to triangulate reliably. The use of error polygons keeps the reliability constant, but does little to alleviate the bias, and may, in fact, intensify it because error polygons close to the receiver are smaller than those far away.

Once one has been alerted to this bias, it is natural to suspect that the bias influenced other regression coefficients. Table 14 presents the linear correlations between the independent variables, and indeed, the density of restricted access light duty roads is significantly correlated with several independent variables. Of the independent variables found to be important in the model, restricted access road density is positively correlated with forest cover and age diversity, but is not correlated with site index, condition, operability or aspect. However, site index, condition, operability, and aspect were found to be highly correlated amongst themselves.

The next step in this type of analysis is usually to streamline the model by eliminating variables that either do not contribute to explaining the variation in the dependent variable, or contribute redundantly. An $R^2C(P)$ analysis (SAS 1979) indicated that the most efficient model utilizing any of these variables included only 3 variables--forest cover type, topographic diversity, and elevation--while explaining just under 9% of the variance. These numbers did not offer much hope of either providing additional insight into bear habitat utilization or building a useful predictive model of bear use of forest stands based on these 19 variables, so no further work with this particular model was undertaken.

Regression models using wildlife data. In order to see if the wildlife data formerly collected by USFS would be useful in

Table 14. Pearson's correlation coefficients[a] for independent variables[b] in the models of bear habitat use.

	AGE	SIT	CON	OPE	MOC	BUL	ASP	MAS	MGR	TPD	EFD	EAD	EAR	ELE	RD1	RD2	RD3	RD4
FCR	.32	-.02	.11	.10	-.04	.19	-.01	.20	.59	.09	-.20	.08	-.29	.05	-.02	-.08	-.02	.11
AGE		.26	.72	.52	.37	.06	.25	.73	.27	.09	.05	.24	-.24	-.20	.03	-.02	-.05	.03
SIT			.58	.24	.26	.00	.18	.32	.28	.27	.04	.21	-.48	-.15	.02	.04	.01	-.09
CON				.40	.32	-.07	.25	.64	.28	.12	.08	.34	-.37	-.03	-.04	.04	.03	.03
OPE					.81	.02	.42	.27	.07	.08	.08	.21	-.03	-.09	-.06	-.05	.02	-.01
MOC						-.05	.32	.35	.11	.18	.18	.07	-.07	-.16	.07	.01	-.07	-.08
BUL							.02	.00	.10	-.05	-.16	-.01	-.09	-.34	.07	-.10	-.14	-.21
ASP								.17	-.03	-.08	.04	.12	.14	-.22	-.17	.02	-.01	-.01
MAS									.24	.14	.12	.20	-.28	-.26	.14	.01	-.05	.01
MGR										.16	-.11	.01	-.36	.14	-.02	.03	.06	.15
TPD											-.03	.14	-.26	-.11	-.04	-.06	-.08	-.08
EFD												.20	.05	-.11	.12	.12	.10	.01
EAD													-.18	.07	-.12	.01	.11	.19
EAR														.03	-.01	-.02	.10	.06
ELE															-.16	.09	.31	.40
RD1																-.05	-.02	-.02
RD2																	-.03	-.06
RD3																		.35

[a]Coefficients greater than .08 or less than -.08 are significant at $p \leq .10$.
Coefficients greater than .12 or less than -.12 are significant at $p \leq .01$.

[b]Variable abbreviations as in Table 13, page 78.

analyzing bear habitat use, the data described in Table 7 (page 39) were included in a regression model using the 4 compartments for which the wildlife data were available. SAS (1979) STEPWISE and RSQUARE procedures were used to choose the best 19 of the 27 (19 original habitat variables plus 8 wildlife variables) variables to use in each model. The R^2 values for the 19 variable models including the wildlife data were compared to the R^2 values for the 19 variable models including only the original 19 variables (Table 15). Table 16 lists the partial regression coefficients for the wildlife variables in each model.

The amount of variance explained by the models using the wildlife data increases by .11 to .15 over the original models. Again, however, the coefficients in Table 16 are difficult to interpret. Hard mast basal area appears to affect stand use by females negatively, yet hard mast production increases stand use, especially in the fall. This would support the previously expressed hypothesis that bears respond to mast production more than cover type. Soft mast variety appears to affect bear use positively across all the models, supporting the hypothesis that diversity contributes to the quality of bear habitat. The partial regression coefficients for the other wildlife variables are more difficult to interpret. Summer soft mast availability appears unimportant to females and exerts a significantly negative effect on use by males. Understory density is insignificant in the fall, has a positive effect on summer use by females, and a negative effect on use by males. Understory

Table 15. Best 19 variables selected by SAS (1979) STEPWISE and use using CISC, derived and wildlife variables.

		Model[a]			
		Females		Males	
	Variable[b]	Summer	Fall	Summer	Fall
ORIGINAL 19 VARIABLES	FCR	x	x	x	
	AGE	x	x	x	x
	SIT	x		x	x
	CON	x		x	
	OPE	x	x		
	MOC	x	x		x
	BUL	x		x	
	ASP	x	x	x	
	MAS			x	x
	MGR		x	x	x
	TPD		x		x
	EFD	x	x		
	EAD	x	x	x	x
	EAR		x	x	x
	ELE	x	x	x	x
	RD1	x	x	x	
	RD2				
	RD3	x			x
	RD4		x	x	x

Table 15 (Continued)

	Variable[b]	Model[a] Females Summer	Females Fall	Males Summer	Males Fall
WILDLIFE VARIABLES	HMB	x	x		x
	HMP	x	x		x
	SMR			x	
	SMV	x	x		x
	SMA		x		x
	USD	x		x	x
	USF	x	x	x	x
	USC	x	x	x	x
R^2 comparison[c]		.176/.288	.131/.281	.253/.383	.530/.653
Error degrees of freedom		208	262	68	18

[a]x indicates that the variable was selected as an independent variable for the best 19 variable model.

[b]Abbreviations for original model variables as in Table 13, page 78, Wildlife variable abbreviations: HMB=hard mast basal area, HMP=hard mast production, SMR=soft mast species, SMV=soft mast variety, SMA=soft mast abundance, USD=understory density, USF=understory food potential, USC=understory cover potential. See Table 6 (page 35) and Table 8 (page 44) for explanations of variables. See Table 16 (page 85) for partial regression coefficients.

[c]Models constructed for the 4 compartments for which wildlife data were available. Comparison is given as: R^2 for model using the 19 original variables/R^2 for model using the 19 selected variables. F values significant for all models at $p \leq .01$.

Table 16. Partial regression coefficient estimates for wildlife data variables used in models of bear habitat use.

	Partial Regression Coefficient Model Estimates[a]			
	Females		Males	
Variable[b]	Summer	Fall	Summer	Fall
HMB	-	- .3		+
HMP	+	+0.1		-
SMV	+0.0	+6.2	+	+
SMA		-2.8	-8.0	-9.9
SMR				
USD	+5.7		-8.9	+
USF	+	+3.1	-9.0	-
USC	+	+4.2	-9.7	-

[a]For estimates significantly different from 0 at $p \leq .10$, the coefficient estimate is given. For estimates not significantly different from 0, only the sign of the estimate is given. All coefficients x 10^3.

[b]See Table 15, page 83, for variable abbreviations.

food and cover seem to affect use by females positively, but affect use by males negatively.

Despite the difficulty in making biological interpretations of the coefficients, the increase in R^2 values in the models using wildlife data over the original models is substantial, and if the Forest Service hopes to eventually build useful models of bear habitat utilization collection of these data should be resumed.

Mortality and Natality

Though population characteristics were not a focus of this study, mortality and natality information was gathered incidentally and may contribute to an understanding of habitat utilization patterns.

Ten collared bears died during the study. One of the deaths (Female 123) was most likely related to drug complications at capture, the other 9 were from hunting. Of those killed by hunters, 5 (2 female, 3 male) were killed legally and 4 (2 female, 2 male) were killed illegally. Additionally, 1 bear (Female 529) was unaccounted for at the end of the study; she may have been killed also. This amounts to a mortality rate due to hunting of 47% to 56% (depending on the fate of Female 529) over the 2 years of the study, with an annual rate in 1982 of 31% and in 1983 of 36% to 43%. Stickley (1961) reported a 33% annual harvest rate of marked bears in Virginia, and Lindsey et al. (1983) report that the annual harvest in Pennsylvania has occasionally approached 30%, but otherwise the rates observed in this study are well above those documented in any other study (Erickson and Petrides 1964 [Michigan], Jonkel and Cowan 1971 [Montana], Piekelek and Burton 1975 [California], Poelker and Parsons 1980 [Washington], Koch 1983 [California]).

In addition to radio-collared animals at least 11 untagged bears were killed in the study area in 1982, and at least 8 in 1983, so that the high harvest rate observed in the collared population is probably indicative of the pressure on the local population as a whole.

All 5 of the collared animals which spent over 50% of their time (judged from number of radio locations and tracking success rates) in areas open to hunting were killed during the study. In fact, it is doubtful that there are any individual bears resident on the TMS for more than a few months at a time; all collared bears on the area during the hunting season were killed, and the only bears trapped on the area before mid-summer appeared to be residents of GSMNP (over 90% of their locations were in the Park).

Three litters were born to radio collared females during the study, including 1 litter of 2 cubs in 1983, 1 litter of 3 cubs in 1984, and 1 litter of an undetermined number of cubs in 1984. Additionally, 4 females were captured while accompanied by cubs, and 2 were captured while accompanied by yearlings. All adult females then, except for 4 whose reproductive condition was unknown because they were either killed before winter denning or unable to be observed in the den, were known to reproduce at some time between January 1982 and March 1984.

It should be noted that Female 531 had a litter of 3 cubs when she was only 3 years old, and so had to have bred at 2 1/2 years. She was captured in June 1983, the summer that she bred, and weighed only 20 kg at that time. Females 529 (5 1/2 years old at capture in 1982) and 532 (7 1/2 years old at capture in 1982) each spent at least 1 year in the study unaccompanied by either cubs or yearlings. Thus, while females in this population may reach reproductive maturity early, they may not reproduce every other year (which is thought to be the minimum time between litters for the species [Kordek and Lindzey 1980]). Data from this study are obviously much too scarce to draw conclusions from, but they do provide an interesting contrast to those of Wathen (1983) who found an average age at first reproduction of 5.2 years and an average interval between litters of 2.15 years in GSMNP.

Den Selection

The winter dens of 12 radio-collared bears (3 males, 9 females) were visited during the study (Table 17). Eight of the dens were on USFS land, 2 were in GSMNP, and 2 were on private land. Of those on USFS land, 2 were in recent clearcuts, 6 were in mature timber. Both of the dens in GSMNP were in stands of large, mature timber, and both of the dens on private land were closely associated with recent clearcuts or clearings.

Johnson and Pelton (1981) noted a strong preference by bears, especially females, for above ground tree dens in the western section

Table 17. Description of winter dens of radio-collared bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, North Carolina, 1983 and 1984.

Year	Bear No.	Sex[a]	Age[b]	Den Structure	Den Location (Compartment-Stand)	Forest Cover Type[c]	Stand Age[b]	Elevation[d]	Aspect[e]	Notes
1983	528	M	3	Rhododendron Thicket-nests	Ed Top (55-14)	WO	62	1017	NW	
1983	529	F	6	Chestnut stump	Poplar Cove (57-15)	YO	58	869	N	2 cubs
1983	530	M	2	Under fallen log	Hurricane Gap (58-09)	WO	62	1049		10 m from logging road
1983	531	F	2	Chestnut oak snag, above ground cavity	Little Bear Mtn. (58-02)	YO	72	942	NE	
1984	531	F	3	Slash pile	Ore Knob (52-14)	WO	7	1036	E	3 cubs
1983	532	M	8	Rock cave	Cold Springs Creek (57-10)	SO	56	640	NW	2 yearlings 70 m from Cold Springs Road
1984	532	F	9	Slash pile	Harmon Den Mtn. (59-27)	WO	2	914	S	
1983	538	F	8	Chestnut oak snag above ground cavity	Scottish Mtn. GSMNP	NC	NA	1152	SE	
1983	526	M	2	Rhododendron thicket	Private land, Tennessee	NC	NA	853	W	On edge of recent clear cut
1984	521	F	4	Laurel thicket	Grassy Branch (58-21)	SO	81	860	SW	At least 1 cub
1984	524	F		Blackberry thicket/slash pile	Private land, Ore Knob	NC	NA	1128	SW	At least 1 yearling, 40 m from pasture
1984	539	F		No. Red Oak above ground cavity	Catteloochee Gaging Station, GSMNP	NC	NA	884	SW	

[a]M = male, F = female.

[b]In years.

[c]WO = White Oak-Red Oak-Hickory, YO = Yellow Poplar-White Oak-Red Oak, SO = Scarlet Oak, NC = Not classified by USFS.

[d]In meters.

[e]N = north, S = south, E = east, W = west.

of GSMNP, and Johnson et al. (1978) have described possible energetic advantages of tree dens over ground dens. In this study only 3 of the 12 dens examined were in above ground tree cavities, and 2 of those were in GSMNP. The only above ground den in Harmon Den was used in 1983 by an immature female; in 1984 this bear denned under a slash pile in a 7 year old clearcut to have her litter of 3 cubs.

Whether the data from this study contradict those from Johnson and Pelton (1981) is not clear. Certainly tree denning habitat, as described by Johnson and Pelton (1981), is not nearly as abundant in Harmon Den as it was in the GSMNP study area, and so tree dens are less available to the Harmon Den bears. Yet individual trees that could be used as dens are present in Harmon Den; in fact, apparently suitable trees were located within 100m of 3 of the ground dens examined. The 5 bears that denned in or near areas of recent disturbance almost certainly had a choice between those and areas of less disturbance.

Wathen (1983) observed a greater tendency on the part of bears who were born in tree dens to use tree dens once they leave their mother than those that were born in ground dens, suggesting that learning and previous experience may play a large part in den selection. Although her previous denning behavior is unknown, Female 531 used a tree den in 1984; she was originally from the Clingman's Dome area, on the edge of the Johnson and Pelton (1981) study area, and had been relocated to the east end of GSMNP by the National Park Service.

The work of Johnson and Pelton (1981), Pelton et al. (1980) and others who have documented use of tree dens by bears in the southern Appalachians has led to the revision of USFS management guidelines for bears (USFS 1981b) so that now suitable den trees are to be maintained in areas where bears are featured. This has raised some controversy among foresters, as the preservation of "wolf trees" suitable for bear dens can interfere with cable or tractor operations, and in order to insure the availability of den trees in the future a certain number of trees that are currently commercially valuable must be left uncut.

Many studies have documented that black bears use a wide variety of structures as dens, including even road culverts (Barnes and Bray 1966) and abandoned buildings. The above ground tree dens used by bears in southern forests are not available to bears throughout the majority of their range. It may be, however, that in a population subject to much human harassment, females with cubs are more secure in above ground dens than in ground dens. A greater recruitment from tree dens relative to ground dens would support this hypothesis, but has yet to be documented.

Effects of Roads

General observations. Before describing the results of the formal analysis some general observations about the relationship between bears and roads should be related. Roads seem to detract from the quality of bear habitat primarily by allowing easy human access to bears. Three of the 5 collared bears killed legally, and at least 2 of the 4 killed illegally, were shot as the bear crossed the road in front of the hunter. Despite the designation of Harmon Den as a bear sanctuary hunters were frequently observed on the Cold Springs Road with guns and hounds, ostensibly to intercept dogs straying into the sanctuary from Hurricane Creek. The restricted logging roads, supposedly protected by locked gates, were used by hunters also; on several occasions contractors with permission to be behind gates for business purposes were seen on the restricted roads with guns and hounds. The relationship between I-40 and bear movement has been previously described, but it is interesting to note here that I-40 may provide an ironic form of protection for bears as hunters were reluctant to release dogs when it appeared that the pursued bear was headed towards I-40; at least 6 hounds were killed by vehicles on I-40 during the study.

The effect of roads on the biotic quality of the habitat may be somewhat beneficial. The resolution of telemetry locations did not allow me to determine how much time was actually spent along roads, but much evidence of bears feeding on pokeberry and blackberry along road margins was noted during the summers. Grass and clover planted as ground cover in road cuts and abandoned roads likely provides spring roughage.

Road density-road crossing analysis. The relationship between road density in the home range and the index of road-crossing frequency (minimum number of road crossings divided by the total number of telemetry locations used to construct the home range) is illustrated in Figures 11, 12, and 13, for abandoned roads, restricted access, improved roads, and unrestricted roads, respectively. Because of the low number of seasonal ranges (39) all ranges were pooled for this analysis, and separate analyses by sex and/or season were not performed. The low density of 4-wheel drive roads in most home ranges precluded analysis of 4-wheel drive road density.

The plot of road density vs. road crossing index for abandoned roads (Figure 11) conforms well to the theoretical line in Figure 3, page 40. Crossing frequency varies directly with density and the intercept is not significantly different from 0 ($p \lesssim .01$), suggesting that abandoned roads probably do not inhibit bear movements.

The plots of road density vs. road crossing index for restricted logging roads and unrestricted improved roads conform well to the theoretical two-segmented line in Figure 4, page 41. The exact lines illustrated in Figures 12 and 13 were derived by trying different road density values to use as the inflection point and looking for the most significant F value. For the logging roads the most significant inflection was found at a density of approximately 1.25 km/km^2; below 1.25 km/km^2 the relationship is similar to that of the abandoned roads, showing a positive slope with intercept not significantly different from 0. At densities above 1.25

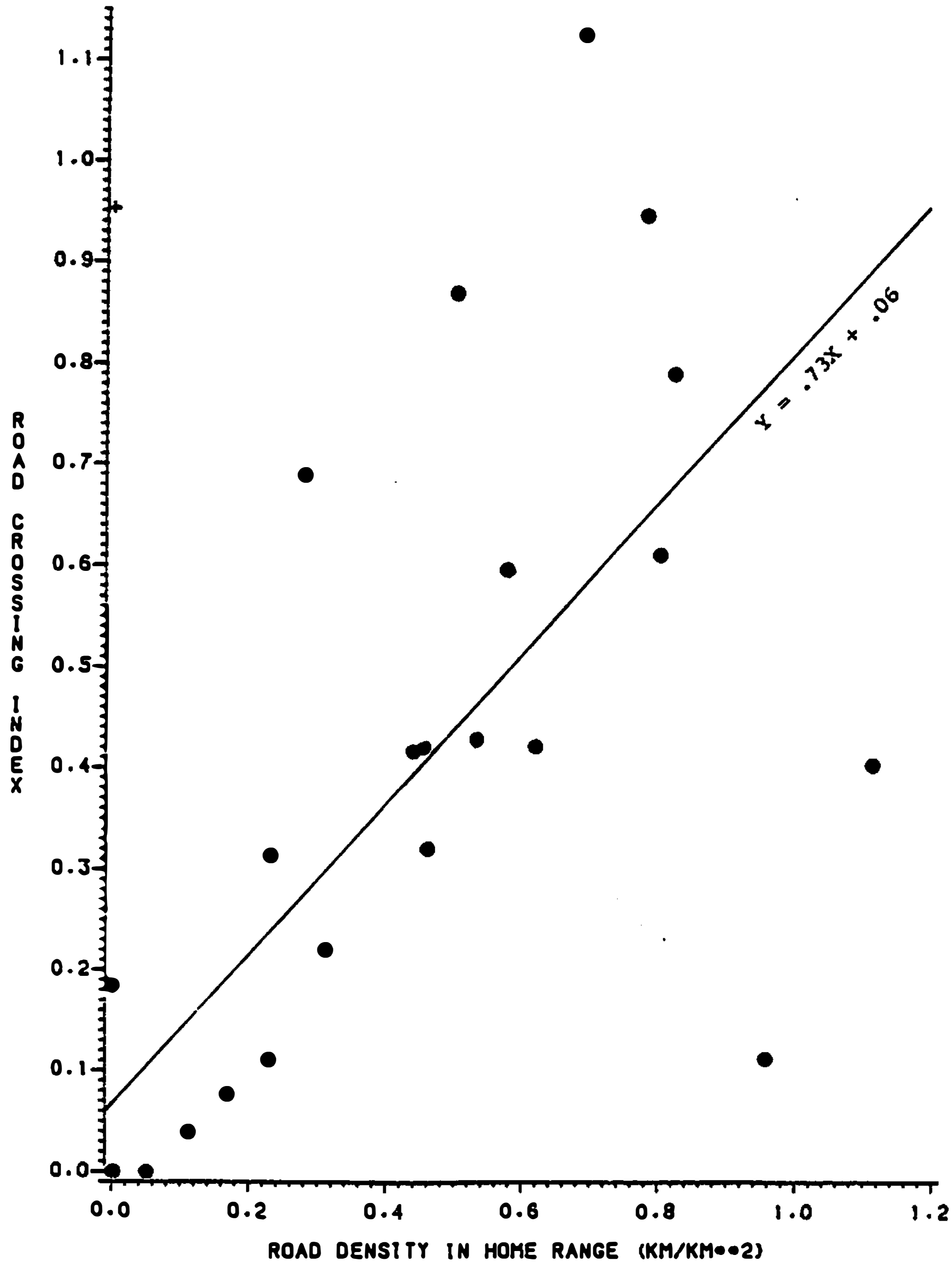

Figure 11. Relationship between abandoned road crossing and density in the home ranges of bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983.

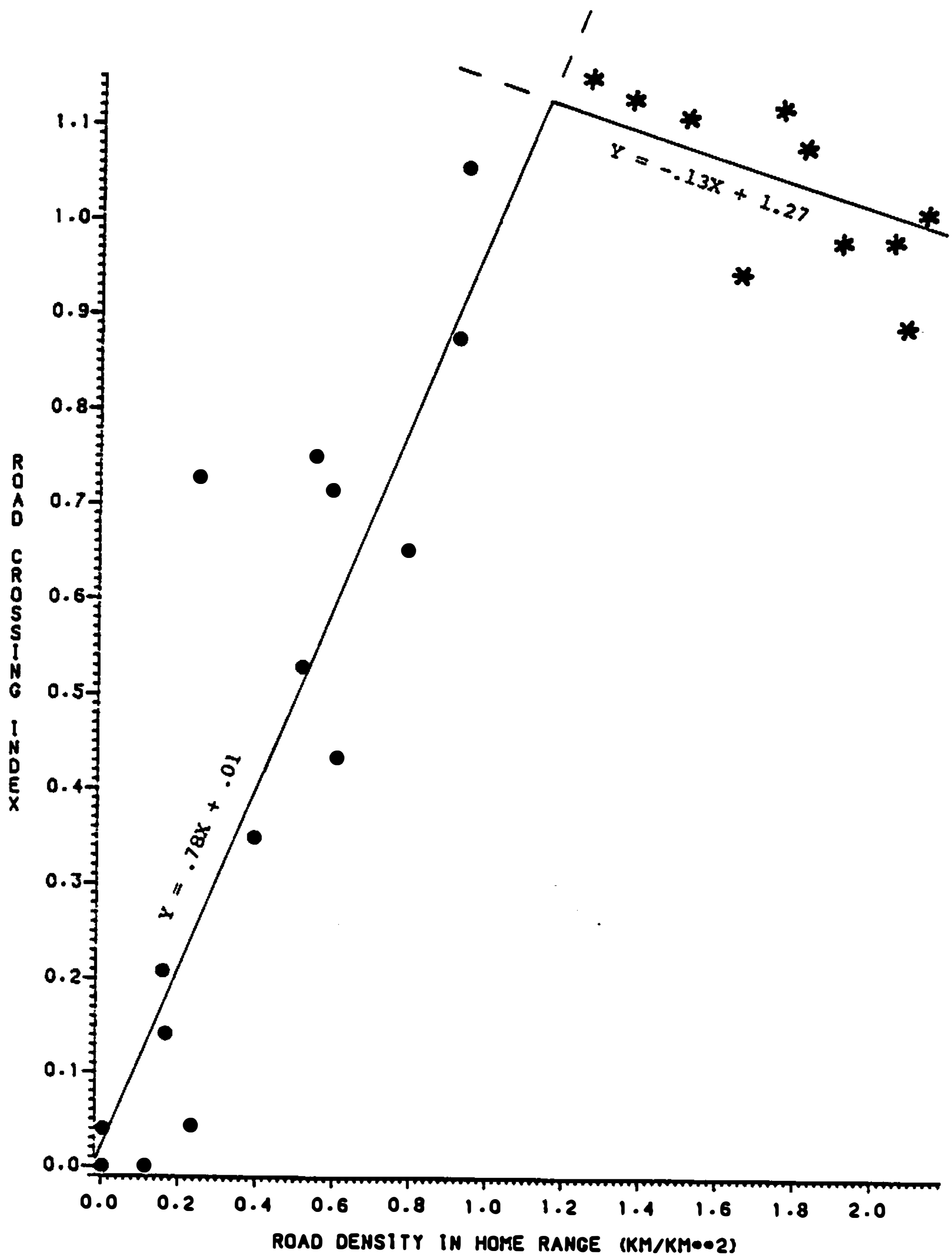

Figure 12. Relationship between restricted-access improved road crossing and density in the home ranges of bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest, 1982 and 1983.

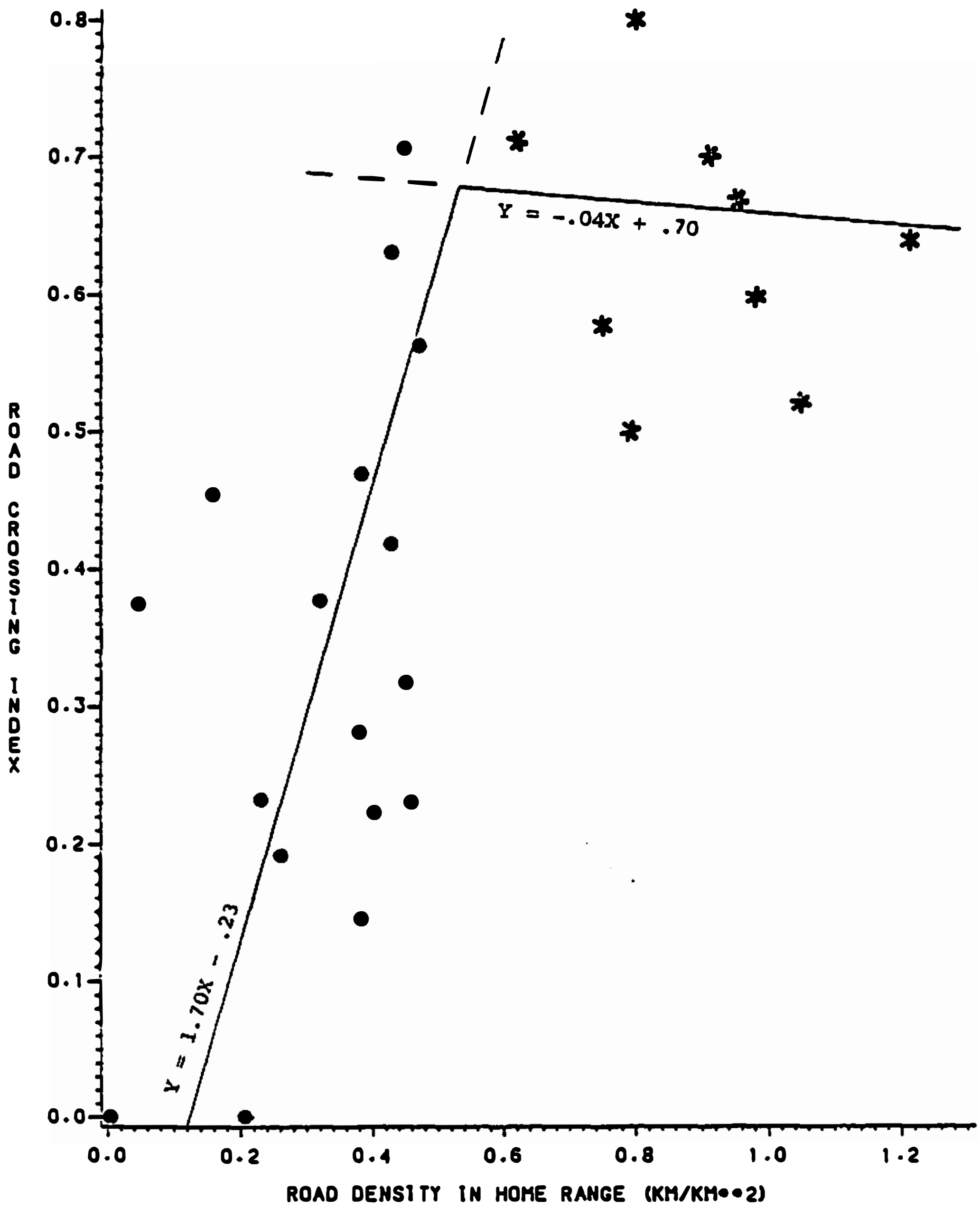

Figure 13. Relationship between unrestricted improved road crossing and density in the home ranges of bears on Harmon Den and the Twelve Mile Strip, Pisgah National Forest 1982 and 1983.

km/km^2 the slope of the relationship appears negative but is not significantly different from 0 ($p > .24$). Thus it appears that bear movement may be inhibited when logging road density exceeds 1.25 km/km^2.

For the unrestricted improved roads the most significant inflection point was found at approximately 0.5 km/km^2; below this point the relationship has a positive slope with intercept not significantly different from 0 ($p = .28$). Above 0.5 km/km^2 the slope is not significantly different from 0 ($p > .99$). Thus it appears that open improved roads may restrict bear movements when road densities exceed 0.5 km/km^2.

There is a large amount of scatter in the plots of Figures 11, 12 and 13, and, in fact, non-segmented lines could be fit to the logging road and to the unrestricted improved road data with statistically significant results ($F = 26.16$, $p \leq .01$ for log roads, $F = 2.07$, $p = .13$ for open roads). The fact that the slope changes significantly from the first segment to the second in each graph supports the idea that bear movements are inhibited by high road densities. Much of the scatter would then be due to the particular spatial relationships between roads and resources in each bear's home range.

The inflection values of 1.25 km/km^2 and 0.5 km/km^2 are similarly a function of the particular spatial relationships between roads and resources, and these inflection values would certainly change if the spatial relationships were altered. Currently approximately 8% of the stands in Harmon Den and the TMS have restricted-access improved road densities exceeding 1.25 km/km^2. Approximately 12% of the stands have unrestricted improved road densities exceeding 0.5 km/km^2; most of these are on the TMS, an area of characteristically low bear density. The exact reasons for roads' restriction of bear movements are unclear, but, as many investigators have previously thought (e.g., Hamilton 1978, Quigley 1982), it is probably in large part due to a learned avoidance of roads; unrestricted roads receive more vehicular traffic than do restricted logging roads and consequently affect bear movements at lower road densities.

V. INTEGRATION

General Habitat Use Patterns and Relationship to Other Areas

Seasonal food availability has been shown to dictate black bear habitat use in many studies, and is indeed a major factor influencing bear habitat use patterns in Harmon Den and the TMS. Garshelis and Pelton (1981), Quigley (1982), and Carr (1983), working in GSMNP, attributed dramatic geographic shifts in activity centers and/or increases in range size in the fall to the patchy distribution of mast compared to the relatively uniform distribution of summer foods. Such dramatic shifts were not generally observed in the 2 years of this study, probably because of a difference in seasonal food distribution between the Harmon Den-TMS and GSMNP study areas. Although mast production may be patchy in a given year, Harmon Den and TMS are 85% covered in mast producing trees, 70% of which are at prime mast producing age. The extensive *Vaccinium* understory mats described by Garshelis and Pelton (1981) and Quigley (1982) in GSMNP are absent from most of Harmon Den. Instead a large amount of summer bear food is found in the rather concentrated areas of recent clearcuts and along roadsides. Thus in Harmon Den the GSMNP situation of uniformly distributed summer foods and patchily distributed fall foods may be somewhat reversed, and this is reflected in less dramatic seasonal shifts in habitat use patterns.

Despite the difference in habitats, the small area of the Harmon Den bear sanctuary appears to support bear densities approximating those of GSMNP as a whole; this is evidenced by the number of mature females caught in the area and the amount of reproduction observed. Only 1 female collared in the sanctuary spent more than 10% of her time outside of the sanctuary; at most 1 of the adult females in the sanctuary was killed by hunters during the study, indicating that the sanctuary is in fact serving its intended purpose of providing a protected reservoir of breeding females. The observed movement of young males out of the sanctuary can be interpreted as dispersal out of this reservoir. The population on Harmon Den is in marked contrast to that on the TMS where it is unlikely that there are any resident breeding bears. The bears that are killed on the TMS in the fall have most likely emigrated from GSMNP (or possibly Harmon Den) during the summer, or been lured into the area by bait in the fall. The population density on TMS thus follows an annual cycle characterized by extremely low density in the spring, density building through immigration in the summer and fall, and near complete decimation during the hunting season.

Harmon Den and the TMS provide essentially the same type of habitat and are subject to the same timber management regime; the difference in population between the 2 areas points out the severity of hunting pressure and underscores the need to protect Harmon Den.

Management Implications

Since it appears that hunting is the major human-related factor affecting the Harmon Den-TMS bear population, it follows that control of the hunting pressure may be the most powerful management tool available. Control of the hunting pressure is certainly the most immediate management tool available--decisions regarding hunting can affect bear populations on an annual basis, while land management decisions generally will affect bear populations slowly, with the course of succession mediating changes in food, cover, and interspersion of resources. But these facts also point out the need for cautious manipulation of the habitat; mistakes made in hunting in 1 year can be relatively easily corrected over the next few years, mistakes made in habitat manipulation may take a century to correct themselves.

Of major concern in Harmon Den is the age structure of forest stands, which will change dramatically over the next 2 decades. Currently the majority of timber is in the 50 to 70 year age class, which also appears to be the age of timber preferred by bears in the area. Over the next 20 years the more than 7000 ha (62.5%) currently in this age class will pass out of the class; it can either be regenerated or allowed to mature into the older classes. Currently 14% of the area is more than 70 years old; bears seem to be indifferent to the 70-90 year old stands, and to avoid the stands as they become decadent.

There are currently just under 1700 ha (14.7%) in the 30 to 50 year age class. Even if none of this is regenerated, there will be a drastic decline (from 7000 to 1700 ha) in the amount of habitat in the preferred age class. The decline will be even greater in the following 2 decades, as less than 13% of the area is currently less than 30 years old. How plastic are the observed habitat use patterns in regard to stand age, and will the patterns change as stand age structure changes? If we assume that use of a stand is related to the mast production of the stand, then it is quite likely that over the next 20 years bears will compensate for the scarcity of 50-70 year old stands by using the increasingly available 70-90 year old stands. After the next 20 years, however, there will be little area covered by timber in the prime mast producing age classes. What occurs then is dependent on how much area is regenerated during the next 20 years. The scenario outlined above is, of course, subject to modification by cover type and site, but as long as even-aged management is practiced it appears that the rough objective of regenerating 10% of the area every decade will not only be tolerated by bears, but will in fact ensure a relatively constant food supply. Units selected for clearcutting must have adequate advance oak reproduction, and silvicultural practices must ensure that mast producing species dominate the stand after 50-70 years (Watt 1979).

The future quality of Harmon Den as bear habitat is dependent not only on the amount and quality of regeneration, but on spatial relationships of the clearcuts, especially with regard to roads. It appears that, for a variety of reasons, roads begin to interfere with bear use of the habitat in Harmon Den when the density reaches 1.25 km/km^2 for open roads and 0.5 km/km^2 for logging roads. Road density in local areas should be kept below these levels.

Additionally, bears seem to benefit from an interspersion of various aged stands, so that ultimately there will be a trade-off between scattering clearcut units throughout the area and keeping road density low. Long range planning is necessary in order to optimize the location of clearcuts and roads. All new log roads should be closed to public traffic, and it would appear that this closure must be better enforced than it was during the years of this study. The benefits of regeneration to bears can be greatly outweighed by increased vulnerability to poaching.

Prospects for a Habitat Capability Model

The models presented earlier in this paper will be of little use in direct management application, as their predictive capability appears low. The R^2 values indicate that only about 15% of the variance observed in bear use of stands can be explained by the models based on CISC and map-derived data, although the amount of variance explained is increased when the "wildlife" variables are included. While these models may lack direct management value, they are of value in indicating what directions future model-building should take. It will be instructive here to attempt to explain the failure of the constructed models.

First, because the models are based on empirical data, assigned parameter values are subject to sampling error and biases. Some of the bias inherent in the telemetry data has been discussed, and there are, no doubt, other biases related to the sampling regime and the particular bears used in the study. The sampling error in the telemetry data was supposedly controlled by the use of error polygons in plotting the locations, but error can be introduced when deciding which azimuths to use in constructing an error polygon. The CISC data are at least as subject to sampling errors as are the telemetry data; USFS personnel have expressed concern over the accuracy of the data collected by contracted foresters. Some variables, such as site index or stand age, are subject to little error in measurement but others, particularly forest cover type, may be more subject to sampling error because continuously variable ecological data must be forced into categorical values. There are also undoubtedly biases involved in the delineation of stand boundaries, a necessarily subjective process.

Secondly, the structure and parameterization of the models are partly responsible for their failure. Models were constructed using linear regression techniques because these are the simplest techniques, not because there was any reason to assume that the modeled relationships are linear. For example, the significance of the estimated coefficient for mast capability would seem to indicate that the effect of stand age would be better modeled as a parabolic function with a peak in bear use at 60 years. Many of the CISC variables were assigned rank values to be used in the regressions, and while the grouping and ordering of variables was done with some biologic justification, the values assigned to the ranks were completely arbitrary; it would be very surprising if the relationships between the assigned values and bear use of stands happened to be linear. In this light the fact that the signs of many of the insignificant coefficient estimates were constant across the models is encouraging--it indicates that there may be trends in the relationship between variables and bear use of the stands but that the arbitrarily assigned values do not linearize the relationships. The performance of these models could undoubtedly be improved by a more careful parameterization of the variables, and the fitting of simple curves where appropriate.

The variables in the models were included because they were readily available, not necessarily because the characteristics they measure were thought to be important to bears. Certainly it is important for efficient and integrated management programs that the data collected for timber management be able to be used in wildlife management, but the possibility of collecting and using other data must be explored. Including understory data, which is routinely collected by some national forests and has been collected in the past by Pisgah, would undoubtedly improve the models' performance. Data more detailed than those in CISC, such as exact volumes and species compositions, are collected from stands in preparation for timber sales; including this information as it becomes available may also improve the performance of the models.

A final explanation of the poor performance of the models may be found not in the models themselves, but in our expectations of them. Studies on bear habitat utilization have related patterns of use to food availability, and certainly the need for satisfying energy and nutrition requirements is of primary importance in shaping these patterns. Other factors--the need for escape cover, for example--also dictate habitat use patterns. But certainly there are still other factors, only indirectly related to habitat characteristics, which influence bear behavior; prime amongst these are social relationships. Information about bear social organization is scarce; how the presence of other bears in an area affects the behavior of an individual is unknown. Additionally, given the documented intelligence and adaptability of the species, it is likely that a certain amount of bear behavior has basis in neither habitat characteristics nor social relationships, but is random exploration that provides an ultimate evolutionary advantage by allowing bears to adapt behaviorally to frequently changing environments.

The telemetry data collected in this study relates only the location of an animal, not what it is doing at that location or how important that activity is. It should not be surprising then that only a part of the variation observed in the telemetry data can be attributed to habitat characteristics.

VI. SUMMARY AND CONCLUSIONS

1. Research was conducted in a portion of Pisgah National Forest from June 1982 through January 1984 to determine habitat use by black bears in relation to forest management.

2. Twenty-one individual bears were captured a total of 25 times during the study. Eighteen of these bears were fitted with radio-collars, and located at daily intervals.

3. Seven bears were tracked from capture to termination of the project; 5 bears were killed during legal hunts; 4 bears were killed illegally; 1 bear lost its break-away collar; 1 bear was unaccounted for at the termination of the project.

4. A total of 1310 telemetry locations were obtained on the 18 bears using ground triangulation or aerial homing.

5. Seasonal home ranges, constructed using the convex polygon method, averaged 3205 ha and 6931 ha for males in summer and fall, respectively, and 872 ha and 1712 ha for females in summer and fall, respectively. In all cases these are larger than bear home range sizes reported in other studies in nearby Great Smoky Mountains National Park (GSMNP).

6. Seasonal and annual shifts in geographic activity centers were determined using the method of harmonic means; inter-seasonal shifts were not significantly different from inter-annual shifts. In contrast, other studies in GSMNP reported significantly larger inter-seasonal shifts.

7. Differences in home range and activity center characteristics between the Pisgah study area and GSMNP are probably due to differences in spatial distribution of resources. In GSMNP fall foods (mostly hard mast) are patchily distributed in comparison with summer foods (mostly soft mast). The situation in Pisgah is somewhat reversed.

8. Irregular and long-range movements were made by 4 bears during the study; in 3 cases these were interpreted as dispersal movements by subadult males.

9. Habitat use patterns were analyzed using Chi squared, ANOVA, and multiple regression techniques. Habitat variables considered in the analysis included those on the U.S. Forest Service "Continuous Inventory of Stand Condition" (CISC) and others measured off topographic and stand maps. A total of 19 habitat variables were considered.

10. Chi-squared analysis showed that Yellow poplar-Oak stands and brush stands, and stands less than 10 years old and stands between 30 and 70 years old were preferred by bears in the summer. Yellow poplar-Oak stands and stands between 50 and 70 years old were preferred in the fall.

11. ANOVA showed stand age to be a significant effect on bear habitat use in summer, while stand age and forest cover type interact significantly in fall.

12. Multiple regression models using the 19 variables explained about 15% of the variance in bear use of individual stands, with much collinearity among predictor variables.

13. Some reasons that the regression models explained so little of the variance were: 1) Some CISC variables were irrelevant to bear behavior, 2) unrealistic structure and parameterization of the models, 3) opportunistic and generalist behavior of bears probably cannot be fully explained on the basis of any habitat parameters.

14. Twelve winter dens were examined during the study. Three were in above-ground tree dens, 9 were in ground dens. Two of the ground dens were in recent clearcuts.

15. The effect of roads on bear habitat use was examined by regressing the frequency of road crossings by individual bears on the density of roads in their respective home ranges. Three types of roads examined were: abandoned logging roads, restricted access logging roads, and improved, unrestricted roads.

16. Abandoned roads did not appear to inhibit bear movements; restricted roads appeared to inhibit bear movements above densities of 1.25 km/km^2; unrestricted roads appeared to inhibit bear movements above densities of 0.5 km/km^2.

17. Management implications were: 1) hunting, both legal and illegal, is the major human activity affecting the study population, 2) current USFS policy of regenerating 10% of the area through clearcutting every decade should be continued as this will ensure a relatively constant amount of timber of prime mast producing age; 3) stands chosen for regeneration should have adequate advance oak

reproduction; 4) the benefits of clearcutting must be balanced against the increased vulnerability of bears to hunting which results from the associated construction of roads.

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APPENDICES

APPENDIX A

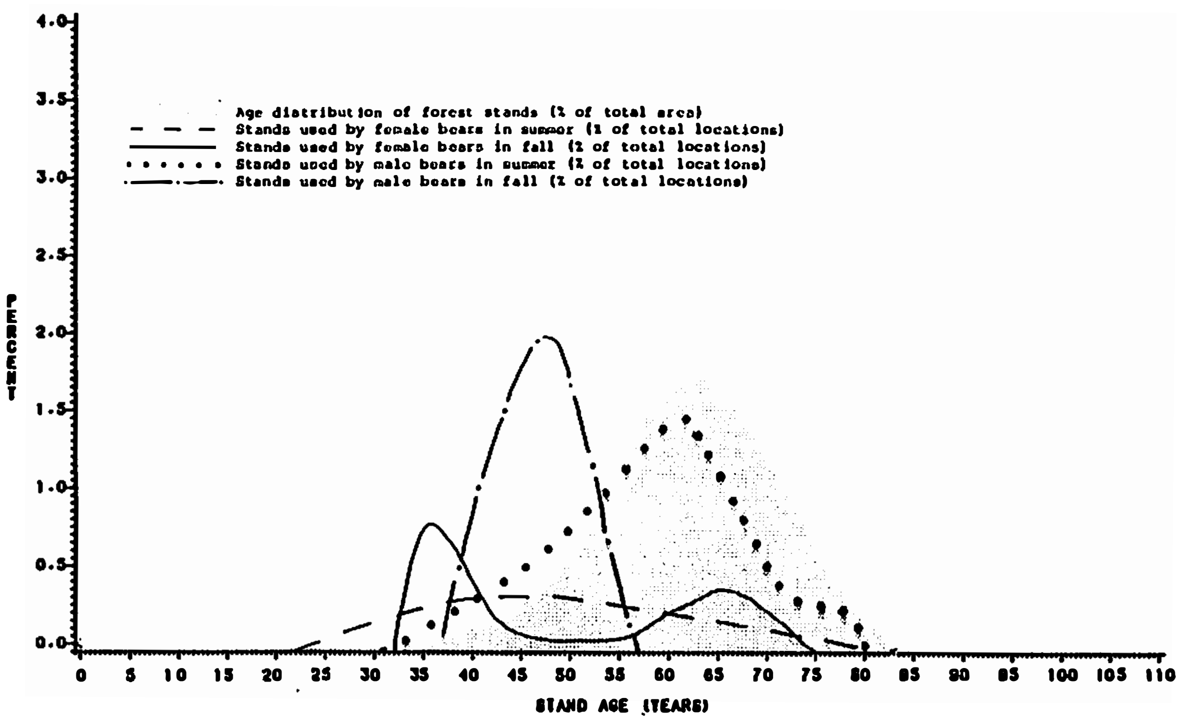

Figure 14. Relationship between age distribution of forest stands and age of stands used by bears for softwood cover types on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX B

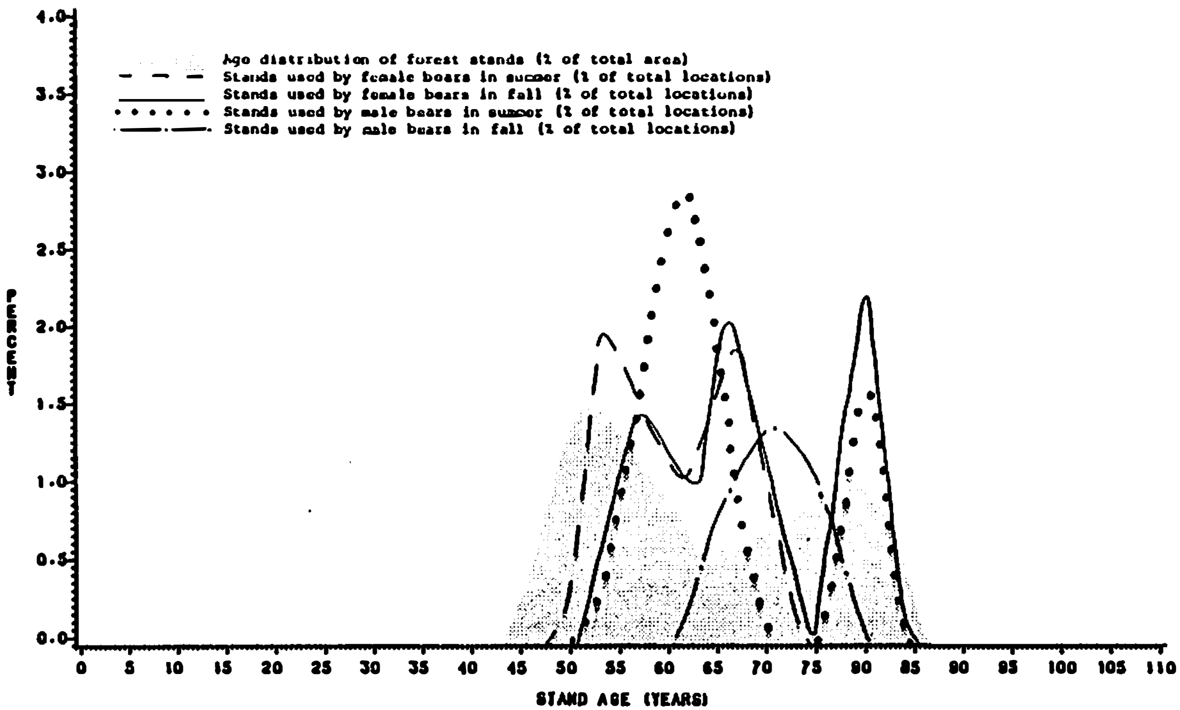

Figure 15. Relationship between age distribution of forest stands and age of stands used by bears for mixed hardwood-softwood cover types on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX C

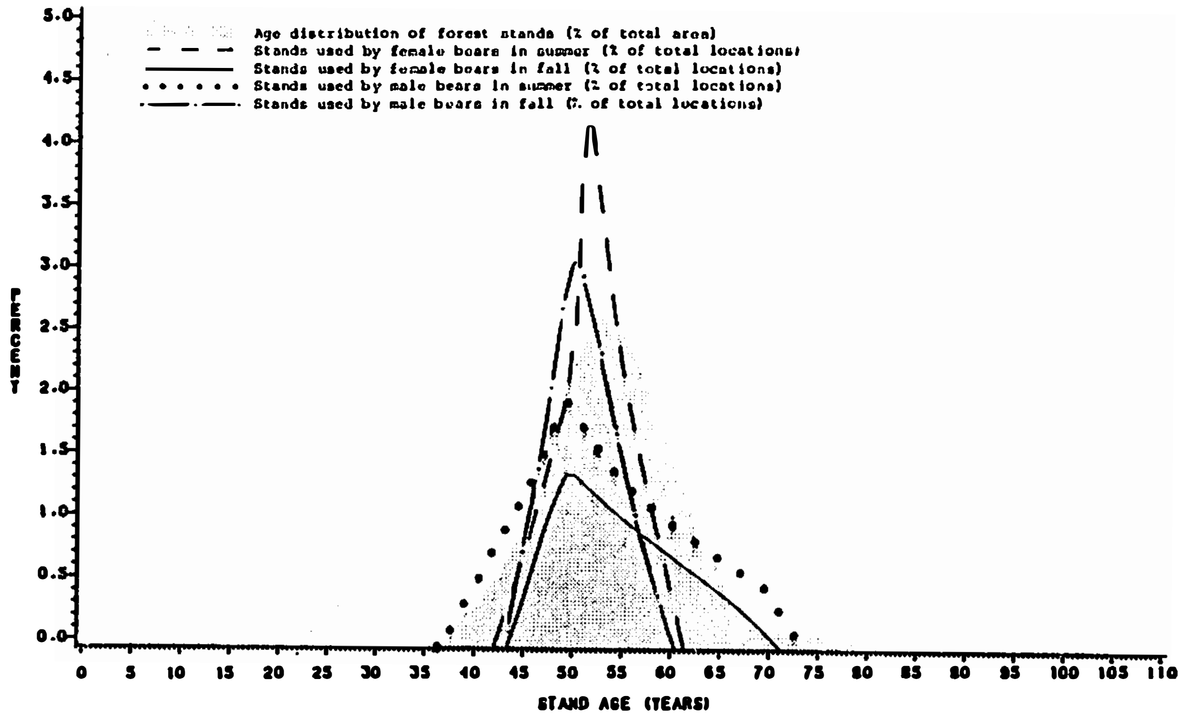

Figure 16. Relationship between age distribution of forest stands and age of stands used by bears for the Yellow Poplar cover type on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX D

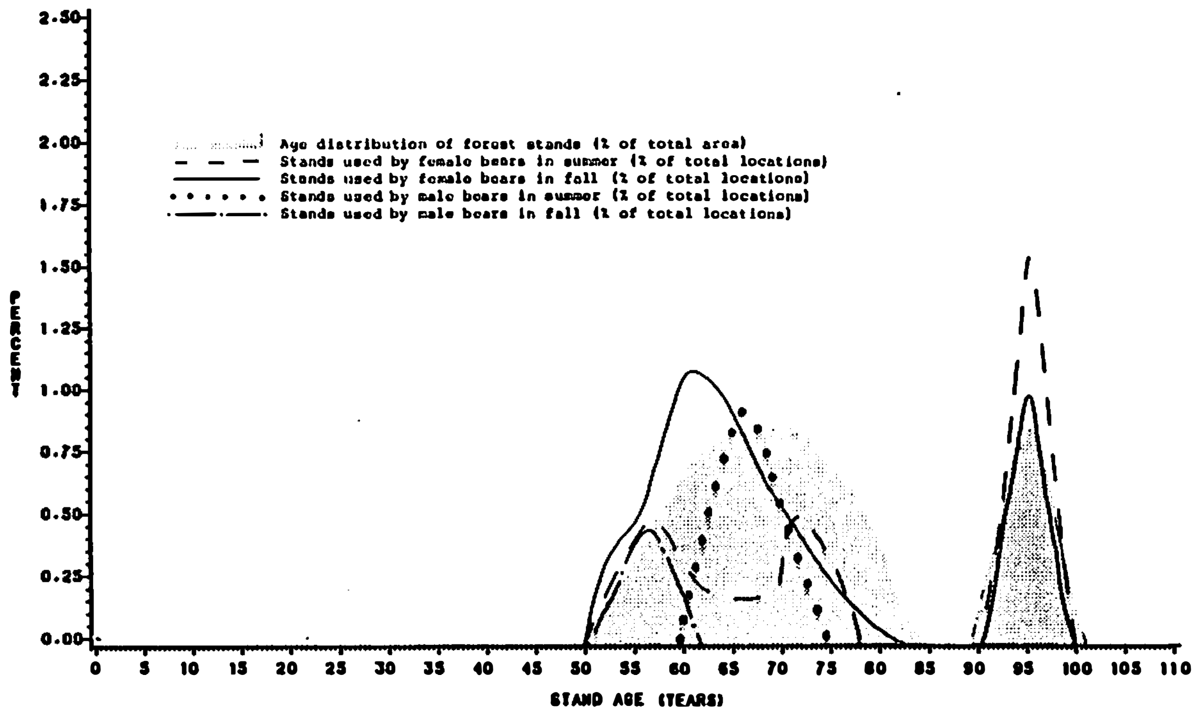

Figure 17. Relationship between age distribution of forest stands and age of stands used by bears for the Chestnut Oak cover type on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX E

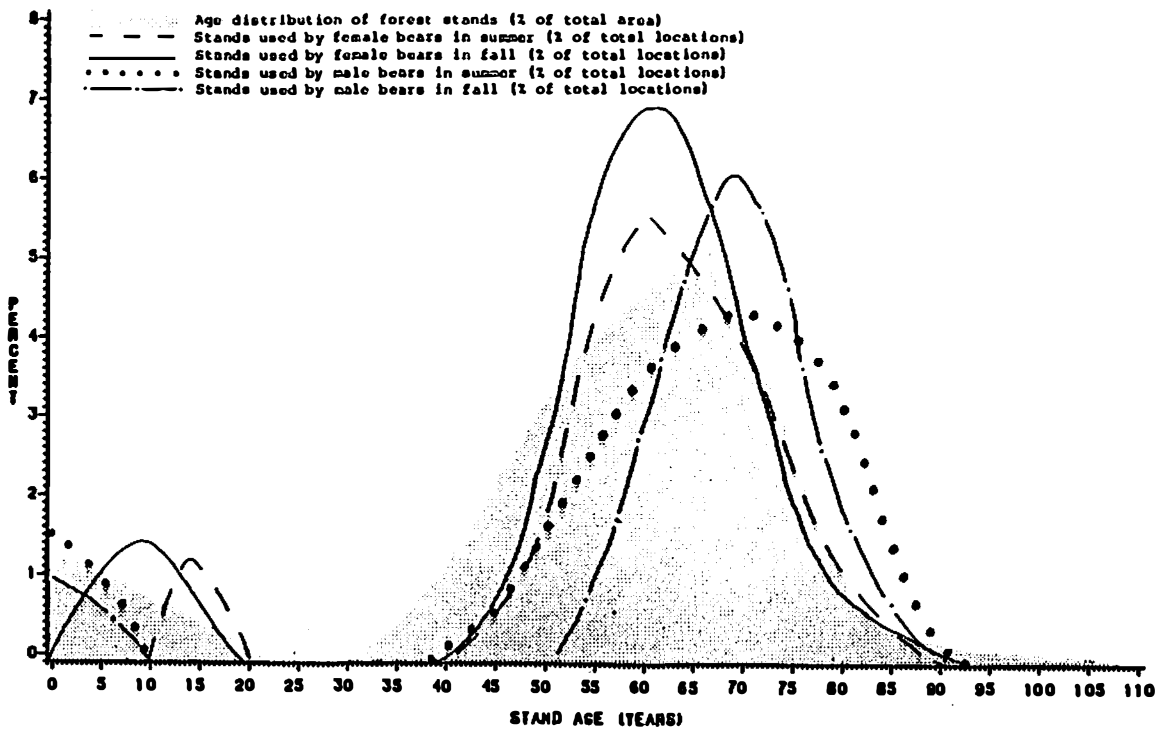

Figure 18. Relationship between age distribution of forest stands and age of stands used by bears for the White Oak-Red Oak-Hickory cover type on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX F

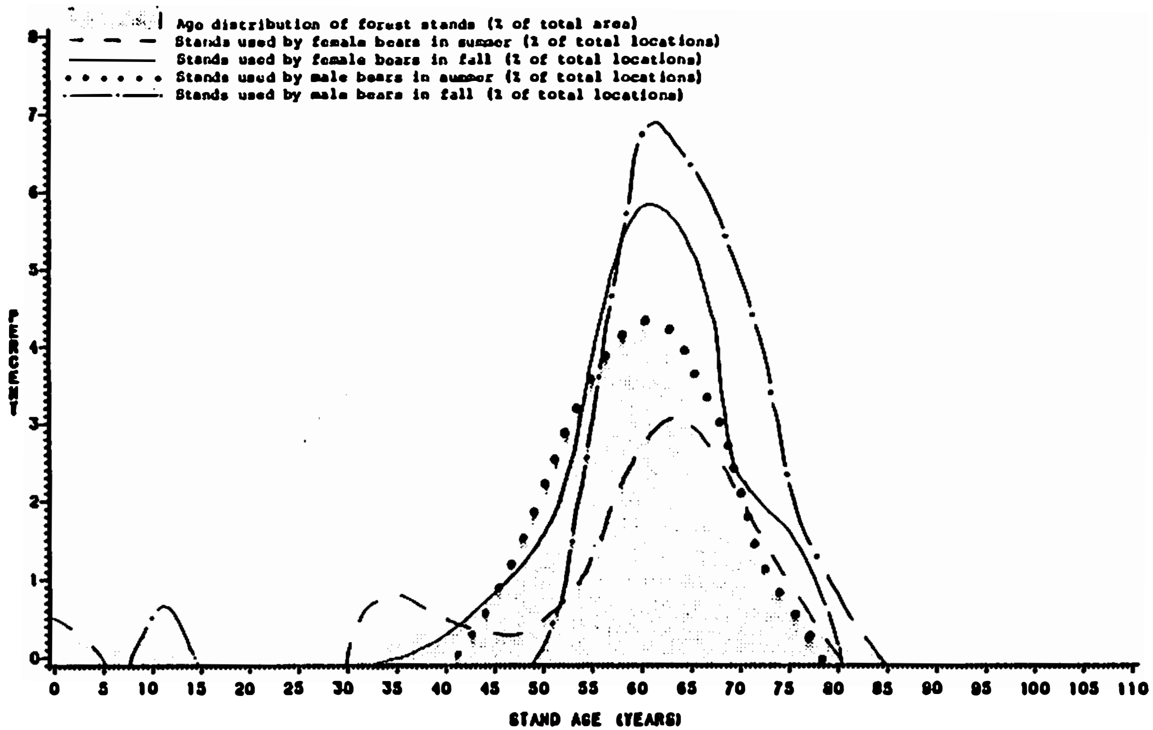

Figure 19. Relationship between age distribution of forest stands and age of stands used by bears for the Yellow Poplar-White Oak-Red Oak cover type on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

APPENDIX G

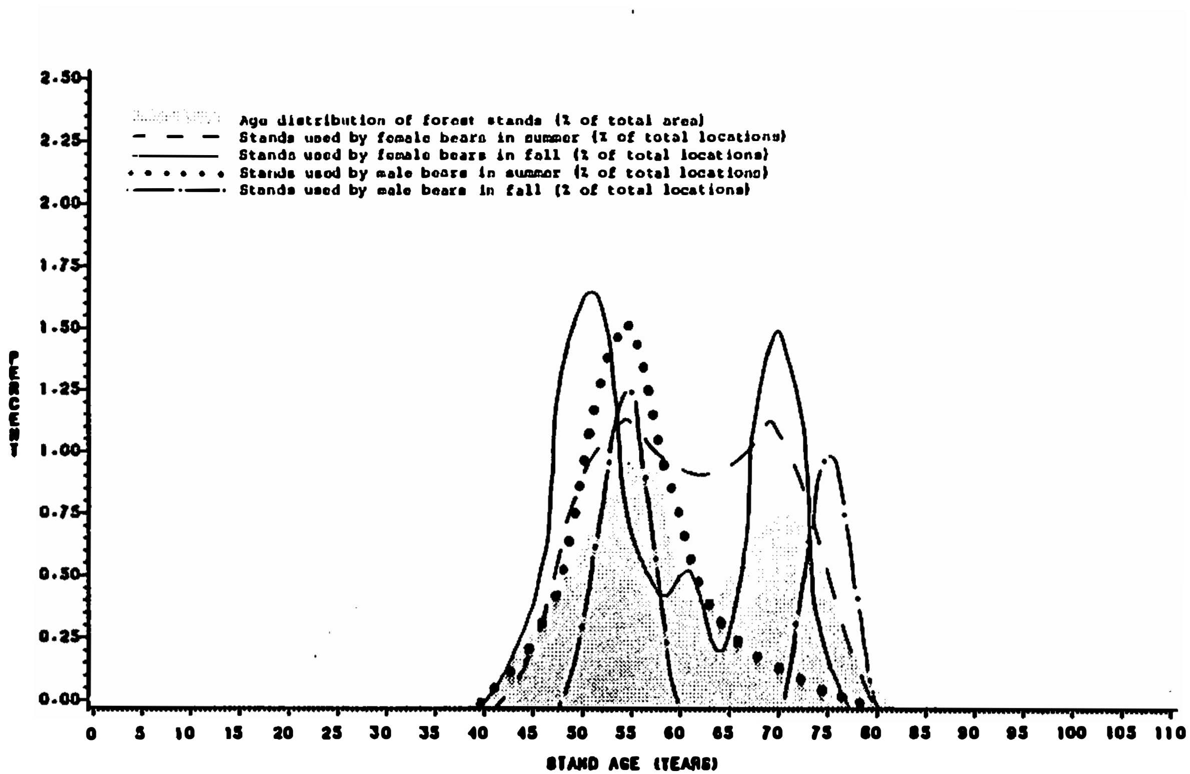

Figure 20. Relationship between age distribution of forest stands and age of stands used by bears for the Scarlet Oak cover type on Harmon Den, Pisgah National Forest, 1982 and 1983. All lines smoothed to generalize the relationships.

VITA

Allan Joseph Brody, son of Garry and Sonia Brody, was born in Montreal, Quebec on November 2, 1958. He graduated from Polytechnic High School in Pasadena, California in 1976, attended the University of North Carolina at Chapel Hill, and received a Bachelor of Science degree in Zoology from the University of California at Davis in December 1981. He entered the graduate program at The University of Tennessee, Knoxville in May 1982, and received a Master of Science degree in Ecology in December 1984.